NATIONAL HEALTH INSURANCE

MEDICAL RESEARCH COMMITTEE

The Influence of Alcohol on Manual Work and Neuro-muscular Co-ordination

---

Approved for publication by the Medical Research Committee, June 27, 1919.

Medical Research Committee.

(National Health Insurance.)

The Hon. WALDORF ASTOR, M.P. (*Chairman*).

The Right Hon. CHRISTOPHER ADDISON, M.D., M.P.

The VISCOUNT GOSCHEN, C.B.E. (*Treasurer*).

C. J. BOND, C.M.G., F.R.C.S. (Hon. Colonel).

PROFESSOR WILLIAM BULLOCH, M.D., F.R.S.

HENRY HEAD, M.D., F.R.C.P., F.R.S.

PROFESSOR F. G. HOPKINS, D.Sc., F.R.C.P., F.R.S.

MAJOR-GENERAL SIR WILLIAM LEISHMAN, K.C.M.G., C.B., F.R.S.

PROFESSOR NOEL PATON, M.D., F.R.S.

SIR WALTER M. FLETCHER, K.B.E., M.D., F.R.S. (*Secretary*).

15 BUCKINGHAM STREET,
STRAND, W.C. 2.

INTRODUCTION

THE present report embodies the chief results of some work done at the instance of the Central Control Board (Liquor Traffic) by Dr. Vernon and his colleagues, whose studies were discussed and approved by the Scientific Advisory Committee to the Board. Dr. Vernon made this investigation while conducting on behalf of the Medical Research Committee some inquiries into industrial fatigue for the Health of Munition Workers Committee (Ministry of Munitions).

The main results obtained from these studies of the effects of alcohol on manual work and the co-ordination of fine muscular movements agree well with those reported by Dr. Mellanby (Report No. 31 of the present series), who made direct chemical estimations of the rates of appearance of alcohol in the blood after drinking, and of its disappearance from the blood under varied conditions. In particular, both these observers, using widely different methods, have shown the important differences between the effects produced by alcohol when taken with or without food respectively, and this is a question of practical interest which has been, as Dr. Vernon remarks, 'curiously ignored by most previous investigators'. The relations between the consumption of food and the physiological effects of absorbed alcohol are so important, as these recent studies have shown, that much previous work upon the effects of alcohol is now seen to have been impaired in value by disregard of the presence or absence of food in the stomach during the experiments.

Dr. Vernon's use of accuracy and speed in typewriting as tests for measuring the influence of alcohol lies open at first sight to the objection that alcohol affects both the amount and the quality of the work done, and that as these two variable factors may be influenced in opposite directions, it is difficult to assign its proper value to each. In the present experiments, however, it was found that the action of alcohol always, with one slight exception, reduced the speed of typing, and increase the number of mistakes; but in order to bring the two variables to terms of a single variable, Dr. Vernon has adopted, in the chief series of experiments, the novel method of restricting voluntarily the rate of work attempted. Finding that the speed of work could be made to vary within narrow limits, he endeavoured to obtain a simple numerical result by taking the number of mistakes made in typewriting as his guide and correcting to a constant typewriting speed, on the supposition that a mistake made may be regarded as the equivalent of a certain (carefully estimated) time unit. In thus restricting speed voluntarily, Dr. Vernon has of course introduced psychological factors of some complexity, which need investigation on their own account. The element of uncertainty due to their introduction would make some hesitate to accept the results expressed in Dr. Vernon's tables for the influence of alcohol, if this influence had been of small magnitude.

Wt. 48039. 228. 1500. 8/19. . O.U.P.

But the effects shown are so pronounced as to leave no doubt that even the smaller doses of alcohol had a definitely harmful influence in his subjects under experiment. His observations of the effects of taking alcohol with food are especially instructive here, because any disturbing factors of the kind just indicated are common to the observations made with and without food respectively, and cannot, therefore, be held to account for the much greater effects of alcohol shown when this is taken on an empty stomach. Again, in many of the experiments both on Dr. Vernon himself and on other subjects, no attempt was made to control the speed of typewriting, and yet these experiments gave similar results to those in which it was controlled.

The Committee are indebted to the Central Control Board for placing this report at their disposal, and they would here acknowledge on Dr. Vernon's behalf the valuable aid which he received from Dr. Sullivan, Captain Greenwood, and Mr. Dreyer.

May 30, 1919.

Medical Research Committee,
15 Buckingham Street,
Strand, W.C. 2.

THE INFLUENCE OF ALCOHOL ON MANUAL WORK AND NEURO-MUSCULAR CO-ORDINATION.

By H. M. Vernon, M.D., with contributions from W. C. Sullivan, M.D., Capt. M. Greenwood, R.A.M.C., and N. B. Dreyer.

CONTENTS

I. The Effects of Pure Alcohol on the Accuracy and Speed of Typewriting.

It is of great practical importance for us to know as accurately as possible what effects upon manual work are produced by the consumption of moderate quantities of alcoholic liquids. Considerable quantities admittedly have very deleterious effects, but the question is whether the equivalent of one to two pints of beer, or of two to four ounces of whisky, appreciably influences the speed and skill of the average manual worker. Investigation of the problem on an adequate scale by direct methods upon the ordinary class of manual worker is so difficult as to be almost impracticable, for even if permission be obtained to carry out the experiment on a sufficient number of workers (e.g. 20 or more), it would be almost impossible to make sure that these workers regularly consumed the experimental dose of alcoholic or control liquid for the three or more weeks over which the experiment ought to last, to the exclusion of the alcoholic drinks to which many of them are

accustomed. Hence it was thought best to try and carry out the experiments upon manual workers of a different social class, who would be more easily controllable and less likely to resent inquiries into personal habits, viz. upon typists. In its physical attributes, typing is comparable to the semi-skilled work of many manual labourers, for a moderate degree of proficiency can be attained by any young person in a few days, and considerable skill in a few weeks. The movements of the hands are quicker than those needed for most kinds of manual work, but not for all. For instance, in the operation of 'mouth-reamering' of small-arm brass cartridge cases, the cases are slipped on and off a rotating spindle at the rate of about three or four a second. Typing has the great advantages that its speed and accuracy can readily be measured, and it has, in fact, been used to some extent by previous investigators for determining the action of drugs. Rivers[1] typed for an hour twice a day for twelve days, during six of which caffeine was taken, and found that the caffeine improved his speed of typing, but made no difference in the number of typing errors. In another series of experiments, lasting eight days, 20 or 40 c.c. of alcohol were taken on three of the days. The results were irregular, but the 40 c.c. of alcohol seemed to diminish the speed of typing. Frankfurther[2] studied the influence of alcohol, tea, and coffee on himself, and found that a dose of 20 c.c. to 40 c.c. of alcohol slightly decreased his speed and considerably increased his errors. Frankfurther typed a long memorized passage, and after practising for thirty-seven days, or until he had acquired a steady speed, he took the alcohol for five days, alternating with non-alcohol days. Rivers appears to have transcribed long passages in his typing, but a source of error is introduced in this way, as passages vary in their ease of transcription. Hence in the experiments to be described a method was adopted which was somewhat similar to that of Frankfurther, but it made the typing approximate much more closely in its character to the repetition work of which most semi-skilled manual labour consists. A short passage which took two minutes or less to type was memorized, and was typed invariably in all experiments. In my own case the passage chosen contained 376 letters or stops and 83 spaces, whilst the travelling typescript holder had to be moved back and jerked on (for a fresh line) seven times. In other words, it necessitated the making of 473 co-ordinated movements. In my fastest typing time, viz. 89·4 secs., this meant an average of 5·3 movements per sec., and in my average time, viz. about 110 secs., 4·3 per sec. As I generally needed to look at the key I wished to strike, it meant that 376 of these movements were co-ordinated movements of both eyes and hands. My own series of experiments lasted altogether 7½ weeks, and during each day of this period I typed my passage as a rule 28 times, and occasionally 60 times, whilst I was careful to do no other kind of typing. The time required for the typing was taken at first by means of a watch with a large central seconds hand, but for the last month with a stop-watch.

I found, like Frankfurther, that alcohol decreased the speed and increased the errors of typing, but it is advantageous for most purposes to co-ordinate and group these two variables together, so as to obtain

[1] W. H. R. Rivers, *Influence of Alcohol on Fatigue*. London, 1908.
[2] Frankfurther, *Psychol. Arbeit.* 6, p. 419, 1912.

a single numerical result to express the alcohol effect. With this end in view, I carried out the majority of the typings in the following manner: I typed my passage seven times, the first time at a medium pace, but the 2nd, 4th, and 6th times either at a pace designed to result in my making, on an average, about one error in the passage, or at a quicker pace designed to result in about three errors. During the 3rd, 5th, and 7th typings I typed at the reverse speed. A concrete instance will make the method clear:—

	Slow typing.		*Fast typing.*	
	Time in Seconds.	*Mistakes.*	*Time in Seconds.*	*Mistakes.*
8.47 p.m.	(115·8)	(1)		
8.50			102·0	3
8.53	110·0	0		
8.56			98·6	1½
8.59	106·0	1		
9.2			98·7	3½
9.5	109·4	1		
Mean	108·5	0·67	99·8	2·67

2·00 mistakes = 8·7 seconds, or 1 mistake = 4·4 seconds.

Here it will be seen that when I was typing the passage at a 'slow' rate I made on an average 0·67 of a mistake, and when at a 'fast' rate, I made 2·67 mistakes. The fast rate was 8·7 secs. quicker than the slow rate, and as 2·00 more mistakes were made, 1·0 mistake would have a time equivalent of 4·4 seconds. The individual time equivalents of a mistake determined in this way varied a great deal, and occasionally more mistakes were made when typing slow than when typing fast, but the averages of the time equivalents observed in five successive weeks were 4·4, 4·6, 4·2, 4·5 and 5·0 seconds per mistake, or were nearly constant. Hence the average equivalent of 4·5 seconds per mistake was always adopted in all the corrections subsequently referred to. This plan of obtaining a time equivalence is a rough method which is approximately correct only under the particular conditions of experiment, and does not hold through a wide range of typing speed. For instance, if one tries to type beyond a certain speed one greatly increases the number of errors, but without achieving any increase of speed. Conversely, an inaccurate typist like myself makes occasional mistakes, however slowly he types.

It will be noted that the first typing in the above scheme is not averaged with the rest. The reason is that this typing is considerably slower (as a rule about 12 seconds) than the rest, and is more irregular, but its special features will be discussed later on. The 'half' mistakes recorded were due to a (correct) key being struck badly, and so making only a very faint typing impression.

Though the typings took less than two minutes each, as a rule, they were repeated only at three-minute intervals. As I began my experiments on this system I continued it for the five weeks for which the main experiment lasted, but it is not recommended as it is wasteful of time. A half-minute between successive typings would be quite sufficient. If alternate slow and fast typings are made, an interval of some sort is required in order to enable one to collect one's thoughts and realize fully the proposed speed of the next typing, but if the

typing is done throughout at a medium speed, as in some of the experiments to be described subsequently, it is best to make the successive typings as fast as possible one after the other.

The Main Experiment.

The main experiment lasted five weeks, during the first and fifth of which I was under normal conditions. In the second week I took 30 c.c. of pure alcohol (to which were added 10 c.c. of fruit syrup, and water to 150 c.c.) with my dinner at 7.0–7.30, and in the fourth week I took 60 c.c. of alcohol (diluted to 200 c.c.) with my dinner. In the third week I drank 30 c.c. of alcohol (diluted to 150 c.c.) at 5 p.m., on an empty stomach, for it was 3¼ to 3½ hours since I had last had food, and I took none until 7.30 p.m., when the typing was finished. As a rule the typing was repeated four times a day, viz. 9.0 to 9.20 a.m., 6.30 to 6.50 p.m., 8.40 to 9.0 p.m., and at 10.30 to 10.50 p.m. The mean times of typing (excluding the first time the passage was typed) are quoted in Tables I to V at the end of the paper. These times were kept to very closely except on the few occasions specially mentioned in the foot-notes.

It will be seen that the times required for typing were fairly steady from day to day, but that the number of mistakes made was much more variable. On the right side of each Table are quoted the means of the typing times and the mistakes of both slow and fast typings, and it will be seen that the average number of mistakes is fairly steady, as it varied only from 1·9 to 2·7 in the first normal week, and from 1·7 to 2·7 in the final normal week. I practised the typing for four days previous to the experimental period, but the average typing times for successive weeks, viz. 122·1, 115·4, 109·6, 107·0, and 106·8 seconds, show that I acquired extra speed with practice, and did not reach an approximate level of speed until the last fortnight.

The averages for the various typing times are recorded at the bottom of the Tables, and they are reproduced again in Tables VI to VIII,

TABLE VI.—*Normal Weeks.*

Mean time at which typing was made.		Time taken.		Mistakes made.		Mean values.		Mistakes corrected to constant typing speed.
		Slow typing.	Fast typing.	Slow typing.	Fast typing.	Time.	Mistakes.	
First normal week (Feb. 8 to 13)	9.11 a.m.	127·1	118·2	1·7	2·8	122·7 } 122·0	2·2	2·4
	6.51 p.m.	124·7	118·1	1·0	3·0	121·4 }	2·0	1·9
	10.2 p.m.	126·0	118·4	1·4	3·8	122·2	2·6	2·6
Final normal week (Mar. 7 to 13)	9.10 a.m.	112·2	103·3	1·9	3·3	107·8 } 106·4	2·6	2·9
	6.42 p.m.	108 9	100·9	1·1	2·4	104·9 }	1·8	1·5
	8.58 p.m.	110·4	102·0	0·9	2·9	106·2	1·9	1·9
	10.42 p.m.	111·0	105·7	1·1	2·7	108·4	1·9	2·3

along with the means of the data obtained in the slow and fast typings. From Table VI we see that during both of the normal weeks the typing speed increased slightly between 9.10 a.m. and 6.47 p.m., whilst the number of mistakes diminished. The improvement of neuro-muscular co-ordination indicated by these data is well known in other kinds of manual work, and it occurs chiefly during the first few hours of the morning. It gradually becomes neutralized and eventually over-powered in the course of the day by fatigue effects. This influence of fatigue is shown in the present data, for the evening typings were slower and showed more mistakes than the 6.47 p.m. typings. In these and other experimental results subsequently recorded, it will be seen that the speed of typing varied comparatively little under all conditions, whilst the number of mistakes might vary fivefold. Hence, in order to obtain a single numerical result to show the effects of fatigue or of alcohol, the number of mistakes is taken as the standard, but this number *is corrected to a constant typing speed*, on the supposition that 4·5 seconds are equivalent to one mistake. In Table VI each normal week is regarded separately, and the mistakes are corrected to the mean typing speed of the 9.10 a.m. and 6.50 p.m. observations in the respective weeks, viz. to 122·0 and 106·4 seconds. Thus the speed at 9.10 a.m. during the last week being 1·4 seconds slower than the mean, and 1·4 seconds being equivalent to 0·3 mistake, the corrected number of mistakes becomes 2·9 instead of 2·6. The corrected mistakes recorded in the last column of the Table show that the diurnal variations of mistakes during the two normal weeks corresponded moderately well. The reason why the mistakes are not corrected to the mean speed of all four sets of daily observations is in order to obtain comparable data to those yielded in the alcohol experiments, when the 9.10 a.m. and 6.50 p.m. observations were the only ones made under *normal* conditions.

In Table VII are shown the effects of taking alcohol with food. The food was eaten between 7.0 and 7.30 p.m., the alcohol being drunk between about 7.5 and 7.25, or at an average time of appoximately 7·15. A typing was made 105 minutes after this time in the 30 c.c. alcohol experiment, and 96 minutes after in the 60 c.c. alcohol experiment. Subsequent experiments showed that these times were too late, as the maximum effect of 60 c.c. of alcohol was found to develop about 40 minutes after its consumption. They were chosen on the strength of Dodge and Benedict's[1] conclusions that the maximum depressive effect of alcohol upon various reflexes occurred at about 95 minutes after its administration. As the alcohol was taken by their subjects some time after any food had been consumed, I thought that the maximum effect of alcohol taken with food would be somewhat later than the time fixed by them.

The data in Table VII show that if the necessary allowance be made for fatigue, the 30 c.c. of alcohol had little if any effect on the speed of typing, but it increased the mistakes by 67 per cent., whereas the data obtained in the last normal week show that fatigue alone increased them only by 6 per cent. between the 6.42 and 9.0 p.m. typings. The influence of the alcohol was specially marked in the slow typings, for the mistakes were then increased 157 per cent. The

[1] Dodge and Benedict, *Psychological Effect of Alcohol*, Washington, 1915, p. 257.

corrected mistake values (corrected to the mean speed of typing observed in the 9.15 a.m. and 6.41 p.m. typings) show 100 per cent. increase at 9.0 p.m., as against a 27 per cent. increase at the corresponding time in the last control week. At 10.40 p.m. they show a 69 per cent. increase, as against a 53 per cent. increase in the control week; or, in other words, the effect of the alcohol had almost disappeared 205 minutes after it was consumed.

From the lower half of Table VII it will be seen that 60 c.c. of alcohol slightly increased the time of typing, whilst it nearly doubled the average number of mistakes. In the slow typings the mistakes were increased 140 per cent., whilst the corrected mistakes show an increase of 116 per cent. at 8.51 p.m. At 10.42 p.m. the increase was only 32 per cent., or considerably less than in the control experiment,

TABLE VII.—*The Effects of Alcohol taken with Food at 7.5 to 7.25 p.m.*

Mean time at which typing was made.		Time taken.		Mistakes made.		Mean values.		Mistakes corrected to constant typing speed.
		Slow typing.	Fast typing.	Slow typing.	Fast typing.	Time.	Mistakes.	
30 c.c. alcohol (Feb. 14 to 20)	9.15 a.m.	119·3	112·0	0·7	3·4	115·6 (114·6)	2·1	2·3
	6.41 p.m.	119·0	108·1	0·7	2·8	113·6	1·8	1·6
	9.0 p.m.	120·1	110·5	1·8	4·2	115·3	3·0	3·2
	10.40 p.m.	122·1	112·0	1·5	3·0	117·0	2·2	2·7
60 c.c. alcohol (Feb. 28 to Mar. 6)	9.10 a.m.	111·7	103·7	2·2	3·8	107·7 (106·6)	3·0	3·2
	6.38 p.m.	109·5	101·8	1·8	3·6	105·6	2·7	2·5
	8.51 p.m.	111·4	105·4	4·3	5·6	108·4	5·0	5·4
	10.42 p.m.	110·1	102·4	2·6	4·3	106·3	3·4	3·3

so not only had the depressant effect of the alcohol entirely passed off, but it appeared to have been followed by a stimulant effect. Still, the data are not adequate enough to permit a definite conclusion. In Fig. 1 the corrected mistake values for the normal weeks and for the alcohol weeks are reproduced diagrammatically. The particular form in which the alcohol curves are drawn depends on results which are discussed later on, but however drawn they show very clearly the onset and duration of the effects. The dotted lines indicate the average mistakes made in the normal weeks.

The mean results obtained in the third week, when 30 c.c. of alcohol (diluted to 150 c.c.) were taken at 5.0 p.m. on an empty stomach, are recorded in Table VIII. The effects were greater than those produced by 60 c.c. of alcohol with food, for 52 minutes after consuming the alcohol the mean typing time was increased 5·6 seconds, and the mistakes were increased 105 per cent. In the slow typings the mistakes

were increased nearly threefold, whilst the corrected mistakes show an increase of 162 per cent. This very marked effect was due partly to the fact that the typing was done at a time which subsequent experiments showed to be only about 22 minutes later than the optimum, for this occurs about 30 minutes after the alcohol is taken. The greater

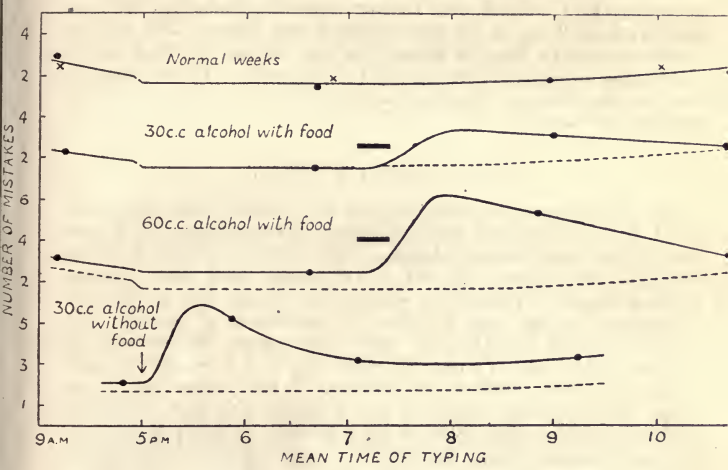

FIG 1.

TABLE VIII.—*The Effects of 30 c.c. Alcohol at 5 p.m. on an Empty Stomach.*

Mean time at which typing was made.	Time taken.		Mistakes made.		Mean values.		Mistakes corrected to constant typing speed.
	Slow typing.	Fast typing.	Slow typing.	Fast typing.	Time.	Mistakes.	
4.50 p.m.	110·2	102·2	1·1	3·0	106·2	2·1	2·1
5.52 ,,	115·5	108·1	3·1	5·5	111·8	4·3	5·5
7.6 ,,	114·0	104·7	1·4	3·5	109·3	2·5	3·2
9.14 ,,	115·8	106·0	1·3	3·3	110·9	2·3	3·3

effect was also due, in small degree, to the alcohol being in somewhat more concentrated form than in the alcohol + food experiments. Though the alcohol was taken in 20 per cent. solution in the one food experiment, and in 30 per cent. solution in the other, its admixture with the food in the stomach must have reduced its effective concentration to something between a third and a half these values,

whereas there was no dilution whatever of the 20 per cent. alcohol in the foodless experiment. Allowing for these two factors, this experiment, coupled with those subsequently described, shows that *at the height of its influence alcohol is about twice as active in upsetting neuro-muscular co-ordination when taken on an empty stomach as when taken with food.* The corrected mistakes observed in the foodless experiment are reproduced at the bottom of Fig. 1, and a comparison with the normal curve seems to indicate that recovery from the alcohol was not complete even at 9.14, or 4¼ hours after it was taken. This lack of complete recovery, whether genuine or not, was not observed in the other experiments which are described subsequently. In any case, one may say that most of the effect had disappeared two hours after the alcohol was taken.

Subjective Effects of Alcohol.

In my own case the subjective effects of alcohol are considerable, but I am probably more susceptible than the average man. I have always been practically an abstainer, and have been absolutely so for the last three years. The 30 c.c. of alcohol with food produced a slight degree of vertigo, but when taken without food it produced considerable vertigo, and a feeling of clumsiness at typing. My fingers appeared sometimes to strike the wrong key in spite of my best endeavours to strike the right one, and I frequently failed to hit the keys plumb in the middle. I felt rather stupid and sleepy, especially after taking 60 c.c. of alcohol with food, but otherwise felt neither mental exaltation nor depression. I found no difficulty in correcting my typing results even at the height of the alcohol effects, but my memory was poorer and more confused. For instance, in experiments to be described subsequently I typed four times successively without any pause at intervals of approximately two minutes, and I began each typing by putting the time, e.g. 6.0, 6.2, 6·4 and 6·6. When I was not under the influence of alcohol I could remember the appropriate time I had to insert without delay, but after alcohol I needed to pause to think, so I found it easier to get the time by looking at the (ordinary) watch which I kept by the side of the stop-watch. The maximum subjective effect undoubtedly came on earlier—probably ten minutes or so—than the effects on neuro-muscular co-ordination, and disappeared earlier than these effects disappeared, but it was not possible to obtain exact data on the point.

Alcohol Tolerance. The present series of experiments offer a good opportunity for determining whether I acquired any alcohol tolerance in the course of the three alcohol weeks. The method by which I investigated the question is best illustrated by giving an example in detail, and the one chosen relates to the week in which 30 c.c. of alcohol were taken without food. A mean was taken each day of the typing times and mistakes in the 4.50 p.m. observations, and the mistakes were corrected to the mean typing speed of the whole week, viz. 106·2 seconds. The same process was repeated for the 5.52 observations, the mistakes still being corrected to the mean typing speed (106·2 seconds) observed in the 4.50 observations. The corrected mistakes were now considerably more numerous than before, because

of the alcohol taken at 5.0 p.m., and Table IX shows the daily excess of these corrected mistakes. Though the excess was irregular, it was distinctly larger in the first half of the week than in the last half,

TABLE IX.—*The Effects of 30 c.c. Alcohol without Food at 5 p.m.*

Date.	Typing at 4.50 (before alcohol).			Typing at 5.52 (after alcohol).			Excess of corrected mistakes.
	Time taken.	Mistakes made.	Mistakes corrected to speed of 106·2 secs.	Time taken.	Mistakes made.	Mistakes corrected to speed of 106·2 secs.	
Feb. 21	109·2	2·1	2·8	113·5	5·2	6·8	4·0
„ 22	107·3	2·2	2·4	115·5	5·0	7·1	4·7
„ 23	103·7	2·2	1·6	111·2	5·4	6·5	4·9
„ 24	109·8	1·9	2·7	112·8	4·1	5·6	2·9
„ 25	104·0	2·3	1·8	108·0	2·5	2·9	1·1
„ 26	106·0	1·9	1·9	111·3	4·6	5·8	3·9
„ 27	103·6	1·9	1·3	110·2	3·3	4·2	29
Mean . .	106·2						3·5

i.e. the diminution in the excess seems to point to an increasing tolerance to the alcohol. However, on repeating this method of investigation with the 6.43 and 8.56 observations made during the two weeks in which alcohol was taken with food, no similar diminution of effect showed itself. In fact there was, if anything, a

TABLE X.—*Excess of Mistakes at 8.56 p.m. (or 5.52) as compared with those at 6.43 p.m. (or 4.50).*

Day of week.	30 c.c. alcohol with food.	60 c.c. alcohol with food.	30 c.c. alcohol without food.	Mean of alcohol experiments.	First normal week.	Final normal week.	Mean of normal weeks.
First	1·9	(1·2)	4·0	2·9	(0·8)	1·2	1·0
Second	1·9	2·0	4·7	2·9	0·0	0·2	0·1
Third	1·2	1·2	4·9	2·4	0·4	0·7	0·5
Fourth	1·8	4·3	2·9	3·0	0·7	0·6	0·1
Fifth	0·1	2·4	1·1	1·1	0·4	0·8	0·6
Sixth	1·7	2·1	3·9	2·6	1·7	1·2	1·4
Seventh	2·6	4·3	2·9	3·3	1·5	0·4	0·6
	1·6	2·7	3·5	2·6	0·8	0·4	0·6

diminution of tolerance in the 60 c.c. alcohol experiment, and the mean of all three sets of data, which is given in Table X, shows that on an average there was no definite change during the course of the week. This absence of tolerance is of significance in another respect, for it shows that my results were not in any way influenced by suggestion. Rivers found in his ergograph experiments that he sometimes achieved a better result on the days in which alcohol or other drug was taken than on control days, as he was more interested in the experiment, and so concentrated more energy upon it. In the typing method it is improbable that suggestion has any effect whatever on the result, for one has to keep one's attention fixed on the work in hand throughout, especially if one is not a skilled typist. One has not only to remember the memorized passage correctly, but one has (at least it was so in my own case) constantly to remind oneself of the intended speed of typing. I myself always tended to go too fast, and thereby to make an undue number of mistakes. The daily excess of corrected mistakes in the normal weeks, which is recorded on the right side of Table X, shows that on an average the 8.56 observations always contained more mistakes than the 6.43 observations, the mean daily excess being 0·6. If this value be subtracted from the mean values observed in the alcohol experiments, we find that the difference, which represents the pure alcohol effect, comes to 2·9 when 30 c.c. of alcohol were taken without food, 1·0 when 30 c.c. were taken with food, and 2·1 when 60 c.c. were taken with food.

Equivalence between Time and Mistakes. As already mentioned, the time equivalent of a mistake was estimated by dividing the mean difference of the number of mistakes made in the fast and slow typings into the mean difference of time taken. The equivalents determined in this way are recorded in Table XI. Though the

TABLE XI.—*Equivalents between Time and Mistakes.*

Approximate time of typing.	Normal week, Feb. 8 to 13.	30 c.c. alcohol with food, Feb. 14 to 20.	60 c.c. alcohol with food, Feb. 28 to Mar. 6.	Normal week, March 7 to 13.	Mean.	Time of typing.	30 c.c. alcohol without food, Feb. 21 to 28.
9.11 a.m.	8·1	2·7	4·9	6·4	5·5	4.50 p.m.	4·2
6.43 p.m.	3·3	5·2	4·2	6·2	4·7	5.52 p.m.	3·1
8.56 p.m.	3·2	6·7	4·5	3·3	4·4	9.14 p.m.	4·9
10.41 p.m.							
Mean . .	4·4	4·6	4·5	5·0	4·6		4·2

average for each week varies only from 4·2 to 5·0 seconds, or is nearly constant, there is much more variation between the individual values. During each of the normal weeks the time equivalents dwindled

rapidly in the course of the day, and a mean of the data for four weeks (the week in which alcohol was taken without food being excluded because of the different observation times) shows a fairly steady, though small, gradation. Though the data are not sufficient to warrant a definite conclusion, it seems probable that the time equivalence of a mistake does undergo definite variations in the course of the day, and tends to become smaller with the onset of fatigue. In other words, a fatigued person, when he quickens up his speed, tends to make mistakes more frequently than a fresh person does for a similar quickening.

Comparison of First and Subsequent Typings. As already mentioned, the first of the series of seven typings made each time was a good deal slower than the rest. The mean times of all the typings observed in the last normal week are shown in Table XII, and

TABLE XII.—*Means of Normal Week Typings.*

	Mean time taken.		Mean mistakes made.	Mistakes corrected to speed of 108·4 secs.	
1st typing	118·4		2·5	4·7	
2nd ,,	108·8		2·4	2·5	
3rd ,,	106·6		2·1	1·7	
4th ,,	106·5	108·4	2·3	1·9	1·7
5th ,,	106·2		1·8	1·3	
6th ,,	105·7		1·9	1·3	
7th ,,	106·9		1·9	1·6	

we see that the first typing was 10 seconds longer than the mean of the whole. Corrected to constant typing speed, the mistakes numbered 4·7, as compared with 1·7 in the subsequent six typings. By comparing the mistakes made in the first typing, after correction to constant speed, against the mean of the mistakes made in the subsequent six typings, it was found that in the normal weeks and the pre-alcohol observation periods of the alcohol weeks the excess of mistakes in the first typing was usually about 2 or 3, as can be seen from Table XIII. When 60 c.c. of alcohol were taken with food, however, the excess of mistakes increased to 5·6, and when 30 c.c. were taken without food, it increased to 6·6. In other words, when, an hour or so after the consumption of alcohol, I *first* began to execute co-ordinated muscular movements, I was relatively much more clumsy than I became after a minute or two's practice. The alcohol induced *an initial excess of clumsiness* which was considerably greater than the average excess of clumsiness indicated by the results recorded in previous pages. This conclusion, if established by subsequent observations, is one of great practical importance with reference to the causation of industrial accidents, for it means that a workman who started his work when under the influence of a certain quantity of alcohol would have at the outset a special liability to make

errors in his co-ordinated movements, i.e. he would be specially liable to meet with an accident, or to spoil his work.

TABLE XIII.—*Mean Excess of Mistakes in the First Typing over those in Subsequent Typings.*

Approximate time of typing.	First normal week.	Final normal week.	30 c.c. alcohol with food.	60 c.c. alcohol with food.	Time of typing.	30 c.c. alcohol without food.
9.11 a.m.	1·9	3·3	2·4	1·9	4.50 p.m.	2·8
6.43 p.m.	2·8	2·5	2·9.	2·7	5.52 p.m.	6·6
8·56 p.m.	1·1	2·7	1·0	5·6	7·6 p.m.	2·9
10·41 p.m.		3·7	1·9	2·6	9.14 p.m.	3·5

In the observations in which 30 c.c. of alcohol were taken with food there was no indication whatever of this special clumsiness in the initial typing, and in the observations described in the next section, when typing was done at short intervals during the onset of the alcohol effects, there was likewise no indication of it. In other words, it looks as if the special clumsiness only develops if a fairly considerable dose of alcohol is taken, and the co-ordinated movements are altogether suspended for some time after.

The Influence of Dilution of the Alcohol.

In the above-described experiments the alcohol was taken in 20 per cent. solution when the dose was 30 c.c., and in 30 per cent. solution when it was 60 c.c. These concentrations correspond to the amount of alcohol present in spirits after dilution with about an equal volume of water, and it is usually admitted that when taken in such a form the alcohol is more potent than if an equal quantity be taken in a more dilute form, e.g. as beer. Hence it was of interest to investigate the effects of dilution of the alcohol by the typing method. For this purpose a different procedure was adopted from that employed in the main experiment. The memorized passage was typed four times successively without any delay between each typing, other than that required to note the time and re-set the stop-watch. Such processes took about 7 seconds, and as the average typing time was about 105 seconds, it meant that active co-ordinated movements were made for about 7½ minutes altogether. This typing was repeated every twenty minutes, or there was a rest of 12½ minutes between the typings. After making three fourfold typings under normal conditions to serve as a control, 30 c.c. of alcohol in the requisite dilution were drunk, and eight more typings were made. In this way the onset, culmination, and disappearance of the alcohol effects could readily be observed. The average number of mistakes made in each of the typings was corrected to the average speed observed in the three initial control observations. The typings were begun at 4 p.m., and the alcohol was drunk at 4.52 to 4.54, or 3½ hours after food was last taken.

In that it would have been unpleasant to drink a large volume of cold liquid quickly, the alcohol was always diluted with warm water, and 10 c.c. of fruit syrup were added as usual. No food was taken until the typings were completed, viz. at 7.28 p.m.

In Tables XIV and XV are recorded the results obtained on two days when a volume of 30 c.c. of alcohol was drunk in 40 per cent. strength, and on two other days when it was drunk in 20 per cent. strength. A mean of the corrected mistakes in each pair of experiments is given, and also a mean of the two pairs of means. The alcohol was drunk in the course of about half a minute at 4.52 in

TABLE XIV.—*The Effects of 30 c.c. Alcohol in 40 per cent. Solution.*

Mean time of typing.	March 20.			March 23.			Mean corrected mistakes.
	Time taken.	Mistakes made.	Mistakes corrected to a speed of 103·1 secs.	Time taken.	Mistakes made.	Mistakes corrected to speed of 103·0 secs.	
4.4 p.m.	106·5	2·0	2·8	106·2	2·8	3·5	3·1
4.24 „	102·1 (103·1)	2·5	2·3	99·8 (103·0)	1·9	1·2	1·8
4.44 „	100·7	3·6	3·1	102·9	2·4	2·4	2·7
4.52 „	alcohol	—	—	alcohol	—	—	—
5.4 „	102·7	5·5	5·4	101·8	6·4	6·1	5·7
5.24 „	106·9	5·9	6·7	101·5	6·0	5·7	6·2
5.44 „	106·7	6·6	7·4	102·7	4·9	4·8	6·1
6.4 „	102·3	5·5	5·3	101·5	3·9	3·6	4·5
6.24 „	100·5	4·4	3·8	101·1	2·6	2·2	3·0
6.44 „	99·5	3·8	3·0	100·0	2·8	2·1	2·6
7.4 „	101·5	4·2	3·8	99·4	3·6	2·8	3·3
7.24 „	101·5	3·5	3·1	100·0	3·6	2·9	3·0

the 40 per cent. dilution experiments, and when typing was begun at 5.0, or 8 minutes later, a very marked effect had already developed. It will be seen from the Table that at 5.4, i.e. the mean of the 5.0 to 5.8 typing, the mistakes were more than twice as numerous as they had been in the previous control period, whilst at 5.24 and 5.44 they were slightly more numerous still. Then they quickly declined, and by 6.24, or 92 minutes after the alcohol was drunk, they were practically normal again. These results are shown diagrammatically in the uppermost curve of Fig. 2. The dotted line curve reproduced at its base is the mean of two control experiments in which no alcohol was taken at all, and it shows a considerable diminution in the mistakes between the first and second typings, and a much slighter

improvement in subsequent typings. When compared with this control, it will be seen that the effects of the alcohol culminated at 5.24, or 32 minutes after its consumption, and there was never quite a complete recovery.

In the two experiments with 20 per cent. alcohol the alcohol was drunk at 4.54, not 4.52, and the effect produced at 5·4 was very much less than before. At 5.24, however, it was even greater than at the corresponding time in the 40 per cent. alcohol experiments, and, as can be seen by comparing the curves in Fig. 2, the effects, taken as a whole, appeared somewhat greater. Probably this result is mis-

TABLE XV.—*The Effects of 30 c.c. Alcohol in 20 per cent. Solution.*

Mean time of typing.	March 17.			March 21.			Mean corrected mistakes.	Mean corrected mistakes in 20% and 40% solution experiments.
	Time taken.	Mistakes made.	Mistakes corrected to speed of 104·7 secs.	Time taken.	Mistakes made.	Mistakes corrected to speed of 102·3 secs.		
4.4 p.m.	106·8	2·9	3·4	106·9	3·9	4·9	4·1	3·6
4.24 ,,	103·8 (104·7)	2·6	2·4	102·2 (102·3)	3·4	3·4	2·9	2·3
4.44 ,,	103·6	1·9	1·7	97·8	3·0	2·0	1·9	2·3
4.54 ,,	alcohol	—	—	alcohol	—	—	—	—
5.4 ,,	105·2	2·9	3·0	97·6	5·4	4·4	3·7	4·7
5.24 ,,	106·0	5·4	5·7	103·0	8·4	8·6	7·1	6·7
5.44 ,,	106·6	3·5	3·9	102·5	7·7	7·7	5·8	5·9
6.4 ,,	108·2	6·0	6·8	102·3	3·9	3·9	5·3	4·9
6.24 ,,	106·4	4·4	4·8	101·1	3·5	3·2	4·0	3·5
6.44 ,,	103·8	2·8	2·6	96·1	4·4	3·0	2·8	2·7
7·4 ,,	104·7	3·7	3·7	98·9	4·4	3·6	3·6	3·5
7·24 ,,	102	1·8	0·6	100·3	3·0	2·6	1·6	2·3

leading, and is due to the smallness of the number of experiments made, so it is best to combine all four experiments, and the third curve in Fig. 2 shows the average result of drinking 30 c.c. of alcohol in 20 to 40 per cent. concentration.

In Table XVI are shown the results obtained in three experiments in which the alcohol was taken in 5 per cent. solution (i. e. diluted to 600 c.c., instead of 75 or 150 c.c.). The alcohol was drunk between 4.53½ and 4.54½, and the typing at 5.4 showed scarcely any effect. At 5.24 there was a considerable effect, and a still greater one at 5.44; but if the curve in Fig. 2 be compared against the 20 per cent. plus 40 per cent. alcohol curve it will be seen that the effects, taken as

a whole, were distinctly smaller. They were about three-fourths as great, and the culmination of the effect was 20 minutes later than in the concentrated alcohol experiments. The subjective effects of the dilute alcohol were distinctly less, and came on much less rapidly than with the concentrated alcohol, but there was no definite difference in

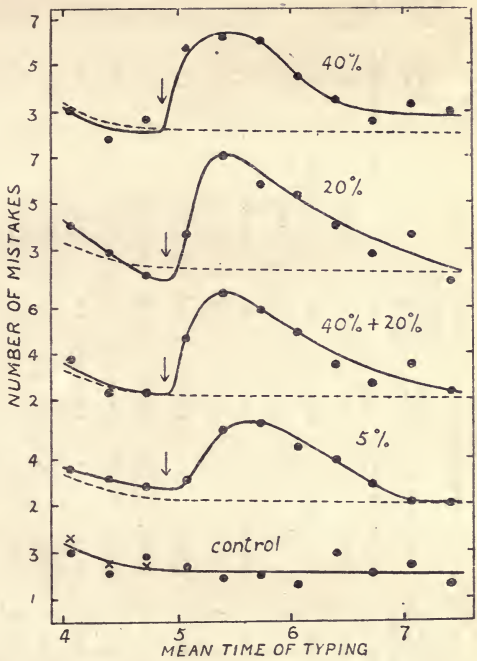

FIG. 2. The Effects of 30 c.c. Alcohol at Various Dilutions taken on an Empty Stomach.

the subjective effects of the alcohol when taken in 40 per cent. or in 20 per cent. concentration.

It may be concluded, therefore, that whilst alcohol taken on an empty stomach in concentrated solution does produce more effect than when taken in dilute solution, the difference is not very marked. No doubt beer is generally drunk off much more slowly than are spirits containing the same amount of alcohol, and this more protracted drinking of itself does much to diminish the alcohol effect of the beer.

TABLE XVI.—*The Effects of 30 c.c. Alcohol in 5 per cent. Solution.*

Mean time of typing.	March 19.			March 22.			March 25.			Mean corrected mistakes.
	Time taken.	Mistakes made.	Mistakes corrected to speed of 106·8 secs.	Time taken.	Mistakes made.	Mistakes corrected to speed of 102·6 secs.	Time taken.	Mistakes made.	Mistakes corrected to speed of 104·1 secs.	
4.4 p.m.	110·9	2·4	3·3	102·8	3·9	3·9	106·8	3·0	3·6	3·6
4.24 ,,	107·5 } 106·8	3·4	3·6	101·0 } 102·6	4·2	3·8	103·0 } 104·1	2·3	2·1	3·2
4.44 ,,	101·9	2·0	0·9	104·1	4·1	4·4	102·6	3·4	3·1	2·8
4.54 ,,	alcohol	—	—	alcohol	—	—	alcohol	—	—	—
5.4 ,,	104·8	2·1	1·7	99·4	3·4	2·7	105·3	4·7	5·0	3·1
5.24 ,,	102·8	4·6	3·7	102·3	5·5	5·4	106·6	5·9	6·5	5·2
5.44 ,,	102·4	5·9	4·9	104·7	5·6	6·1	108·0	4·6	5·5	5·5
6.4 ,,	102·7	3·9	3·0	100·8	6·4	6·0	104·6	4·3	4·4	4·5
6 24 ,,	102·8	3·7	2·8	101·7	4·8	4·6	104·9	4·2	4·4	3·9
6.44 ,,	104·1	2·4	1·8	102·2	4·1	4·0	102·7	3·0	2·7	2·8
7.4 ,,	102·0	2·5	1·4	99·2	2·6	1·8	104·4	3·2	3·3	2·2
7.24 ,,	102·5	1·5	0·5	104·9	3·2	3·7	98·5	2·9	1·7	2·0

The experiments recorded in Table XVII are the control experiments when no alcohol was taken. These results are reproduced in the bottom curve of Fig. 2. The crosses indicate the average numbers of mistakes made in the three control typings of the seven alcohol experiments.

TABLE XVII.—*Control Experiments.*

Mean time of typing.	March 24.			March 26.			Mean corrected mistakes.
	Time taken.	Mistakes made.	Mistakes corrected to speed of 104·6 secs.	Time taken.	Mistakes made.	Mistakes corrected to speed of 105·1 secs.	
4.4 p.m.	105·8	3·4	3·7	104·8	2·3	2·2	3·0
4.24 „	101·5 | 104·6	1·8	1·1	105·3 | 105·1	3·1	3·1	2·1
4.44 „	106·4	2·9	3·3	105·3	2·3	2·3	2·8
5.4 „	104·0	2·1	2·0	104·8	2·9	2·8	2·4
5.24 „	102·1	1·9	1·3	105·0	2·4	2·4	1·9
5.44 „	103·2	2·1	1·8	105·9	2·0	2·2	2·0
6.4 „	99·0	3·1	1·9	104·3	1·5	1·3	1·6
6.24 „	101·8	3·4	2·8	104·5	3·1	3·0	2·9
6.44 „	96·2	2·6	0·7	104·4	3·6	3·4	2·1
7.4 „	98·8	3·2	1·9	100·3	4·0	2·9	2·4
7.24 „	100·6	3·1	2·2	102·4	1·6	1·0	1·6

The Influence of the Quality of the Food on Alcohol Effects.

In the previously described experiments in which alcohol was taken with food, the diet was similar to that eaten under ordinary conditions, though it was mostly vegetarian and poor in fats. Care was taken not to drink any of the alcohol until a fair amount of food had been eaten, so as to prevent the conditions of absorption resembling those obtaining in the experiments on an empty stomach. It was thought to be of interest to make a few experiments in which the diet differed substantially, so the effects of fatty and fatless food were tried. Two experiments were made with each kind of diet. The fatty food eaten consisted of sardines and oil, meat, cheese, butter, and other food calculated to contain about 55 grams of fat, whilst the fatless food consisted of beans, tomatoes, bread, rice, and jam, or food calculated to contain not more than 4 grams of fat. Three or four fourfold typings of the character above described were made at 20-minute intervals before the meal, which was taken at 7.0 to 7.30. The alcohol taken with it (60 c.c. diluted to 200 c.c.) was drunk at an

average time of about 7.16. Immediately after the meal the typings were begun again, and were continued at 20-minute intervals for the next 3¼ to 3¾ hours. The mistakes were corrected to constant typing speed as before, and the results obtained are recorded in Tables XVIII and XIX. The times of typing in each pair of experiments differed by 3 minutes, but this is practically a negligible difference, so means

TABLE XVIII.—*The Effects of 60 c.c. Alcohol with Fatless Food.*

Mean time of typing.	March 15. Time taken.	March 15. Mistakes made.	March 15. Mistakes corrected to speed of 106·4 secs.	March 18. Time taken.	March 18. Mistakes made.	March 18. Mistakes corrected to speed of 104·6 secs.	Mean corrected mistakes.
6.6 p.m.	106·2	3·0	3·0	106·9	1·0	1·5	2·3
6.25 „	107·6 (106·4)	2·4	2·7	105·6 (104·6)	1·8	2·0	2·3
6 47 „	105·4	1·6	1·4	101·4	2·4	1·7	1·6
7.5 to 7.25	alcohol	—	—	alcohol	—	—	—
7.37 p.m.	108·8	3·9	4·4	108·2	6·2	7·0	5·7 } 6·1
7.57 „	108·2	4·9	5·3	107·3	7·1	7·7	6·5 }
8.17 „	109·3	5·7	6·3	107·0	5·8	6·3	6·3 } 6·4
8.37 „	109·2	5·0	5·6	107·3	7·0	7·6	6·6 }
8.57 „	106·8	4·9	5·0	106·1	5·5	5·8	5·4 } 4·9
9.17 „	105·7	3·5	3·3	107·3	4·6	5·2	4·3 }
9·37 „	106·7	4·9	5·0	105·4	5·0	5·2	5·1 } 4·6
9·57 „	107·1	2·9	3·1	105·7	5·1	5·3	4·2 }
10.17 „	106·3	4·6	4·6	104·7	3·3	3·3	4·0 } 3·8
10.37 „	107·6	3·9	4·2	108·1	2·0	2·8	3·5 }
10.57 „	—	—	—	102·5	3·1	2·6	2·6

have been taken between the results of the two experiments in each case, and these means have been grouped so as to give the most even result. These results are shown diagrammatically in Fig. 3, and it will be seen that the maximum effect of the alcohol in each case developed very soon after the meal was completed, and then gradually diminished till in the fat-free experiment it reached, or nearly reached, normal level three hours later. In the fatty meal the initial effect produced by the alcohol was rather smaller, but it did not wear off nearly so rapidly, and even 3¾ hours after the meal there was still a considerable alcohol effect.

These experiments are not sufficiently numerous to base any very safe conclusions upon, but they strongly suggest that the more fat

TABLE XIX.—*The Effects of 60 c.c. Alcohol with Fatty Food.*

Mean time of typing.	March 14. Time taken	March 14. Mistakes made.	March 14. Mistakes corrected to speed of 110·1 secs.	March 16. Time taken.	March 16. Mistakes made.	March 16. Mistakes corrected to speed of 107·9 secs.	Mean corrected mistakes.
5.42 p.m.	104·7	2·6	1·4	113·3	2·5	3·3	2·4
6.2 „	—	—	—	103·8	1·3	0·4	0·4
6.22 „	113·1 (110·1)	3·5	4·2	107·5 (107·9)	3·4	3·3	3·8 (2·1)
6.42 „	112·6	1·8	2·4	107·0	2·1	1·9	2·2
7 5 to 7.25	alcohol	—	—	alcohol	—	—	—
7.30 p.m.	112·3	3·6	4·1	120·5	7·7	10·5	7·3
7.50 „	111·4	4·6	4·9	111·8	7·4	8·3	6·6 (6·1)
8.10 „	106·1	2·8	1·9	109·3	6·4	6·7	4·3
8·30 „	112·1	5·3	5·7	107·6	6·0	5·9	5·8
8.50 „	108·2	5·5	5·1	107·6	5·4	5·3	5·2 (5·5)
9.10 „	108·6	5·4	5·1	109·3	6·1	6·4	5·7
9.30 „	109·4	5·1	4·9	106·7	5·5	5·2	5·1 (5·4)
9.50 „	114·6	6·1	7·1	106·6	5·4	5·1	6·1
10.10 „	111·1	3·0	3·2	107·7	4·6	4·6	3·9 (5·0)
10.30 „	115·5	3·2	4·4	114·0	6·6	8·0	6·2
10·50 „	105·6	2·5	1·5	105·5	5·4	4·9	3·2 (4·7)

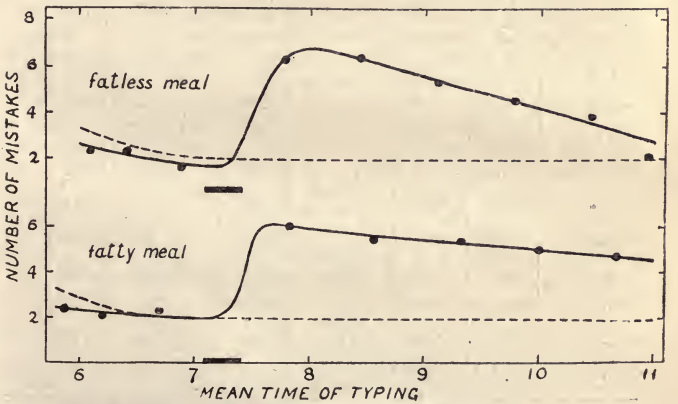

FIG. 3. The Effects of 60 c.c. Alcohol taken with Food.

present in the food the slower the absorption and metabolism of the alcohol taken at the same time. Fatty food is well known to be digested more slowly than fatless food, and a delay in the digestion of the meal as a whole would inevitably delay the complete absorption of the alcohol taken with it. But the fat acts also in another way. It has a considerable solvent power for the alcohol, so a portion of the alcohol cannot be absorbed until the whole of the fat is absorbed likewise.

The Influence of the Quantity of Alcohol taken.

The main experiment showed that when 60 c.c. of alcohol were taken with food, the effect produced was about twice as great as when 30 c.c. were taken. In order to determine more exactly the relative effects of the quantity of alcohol, a few experiments were made by the method of typing at 20-minute intervals, before and after drinking alcohol on an empty stomach. In two experiments, 20 c.c. of alcohol were taken about 3 hrs. 10 min. after food, and in one experiment 40 c.c. were taken. In each case the alcohol was diluted to the same volume, viz. 150 c.c., as in one of the previously described series of experiments with 30 c.c. of alcohol, or the concentration of the alcohol in the various experiments was 13·3, 20, and 26·7 per cent. respectively. It was thought that, in comparing the effects of quantity of alcohol, the conditions would be more comparable if the total volume of liquid were kept constant and the concentration variable, rather than concentration constant and volume variable.

TABLE XX.—*The Effects of 20 c.c. and 40 c.c. Alcohol without Food.*

Mean time of typing.	20 c.c. alcohol in 13·3 % solution.			40 c.c. alcohol in 26·7 % solution.		
	Corrected mistakes (1).	Corrected mistakes (2).	Mean.	Time taken.	Mistakes made.	Mistakes corrected to speed of 107·6 secs.
4.4 p.m.	2·0	1·0	1·5	109·2	1·4	1·8
4.24 ,,	0·0	2·0	1·0	108·5 } 107·6	2·5	2·7 } 1·6
4.44 ,,	0·5	1·2	0·8	105·0	1·1	0·5
4.54 ,,	—	—	alcohol	alcohol	—	—
5.4 ,,	1·2	0·1	0·6	105·2	2·6	2·1
5.24 ,,	1·7	1·2	1·4 } 1·1	110·9	4·0	4·7
5.44 ,,	1·1	0·5	0·8	119·8	5·3	8·0
6.4 ,,	1·0	0·1	0·6 } 0·9	113·0	3·0	4·2 } 6·2
6.24 ,,	2·1	0·4	1·2	112·9	7·0	8·2
6.44 ,,	1·7	0·7	1·2 } 0·6	109·3	2·9	3·3 } 4·0
7.4 ,,	0·0	0·0	0·0	110·2	4·1	4·7
7.24 ,,	0·3	—	0·3	106·1	3·2	2·9

The results of the experiments are recorded in Table XX, and they are reproduced graphically in Fig. 4. It will be seen that the 20 c.c. of alcohol were almost without effect, whilst the 40 c.c. had considerably more effect than 30 c.c., and distinctly reduced the speed of typing, as well as its accuracy. However, the effect is not as great as one would expect. The probable explanation is that these experiments with 20 and 40 c.c. of alcohol were made about nine months after those with 30 c.c. of alcohol, and only a fortnight after other experiments in which 45 to 60 c.c. of alcohol were taken on an empty stomach. These larger doses of alcohol probably reduced my susceptibility to alcohol to some extent. In any case, one may conclude that whilst 30 c.c. of alcohol greatly reduced the accuracy of my typewriting, two-thirds this quantity had a very small effect indeed. Experiments on other subjects, to be described later on, point to a similar conclusion, and show that, so far as typewriting is concerned, alcohol below a certain very moderate amount is practically without influence.

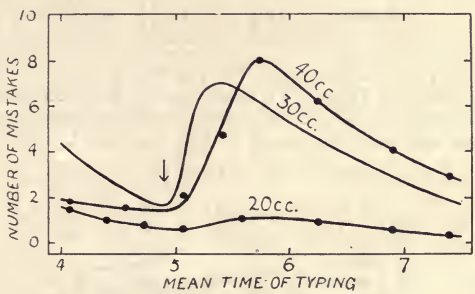

FIG. 4. The Effects of various quantities of Alcohol.

Further experiments upon the influence of alcohol on typewriting were made, at my suggestion, by Mr. N. B. Dreyer, of Trinity College, Oxford. Mr. Dreyer had no previous experience of typing, but after a fortnight's practice he was able to type sufficiently fast to get reliable results. He continued to make experiments on the influence of alcohol and alcoholic liquids on most days during the next two months. At first his average time for typing a memorized passage was 71 secs., but after ten days it fell to 62 secs., and in the next seven weeks it fell only to 56 secs., or he quickened up rather less than I did in the course of my five weeks' experiment. Mr. Dreyer followed nearly the same experimental procedure as myself. He typed the passage six times altogether, at slow and fast rates alternately, and from the data so obtained he calculated the numerical equivalent of a mistake, and thereby corrected his results to a constant typing speed. His 'time equivalent of a mistake' averaged 15 secs., or was more than three times as long as my own. Mr. Dreyer is practically an abstainer, and his susceptibility to alcohol diminished somewhat during the course of his experiments. Hence the experiments of any series were considered comparable only if they were made within a few days of one another.

Upon the effects of quantity of alcohol eight experiments were made. In all of them the alcohol was taken in the afternoon, three or more hours after food. Experiments were made with 20, 25, and 30 c.c. of alcohol in 20 per cent. strength, and another series with 30 c.c. of

TABLE XXI.—*The Effects of 20 to 30 c.c. of Alcohol without Food on N. B. D.*

Dates of Experiments.	Quantity of alcohol taken.	Concentration.	Number of mistakes made.			
			Before alcohol.	½ hr. after alcohol.	1 hr. after alcohol.	2 hrs. after alcohol.
May 11 and 17	20 c.c	20 %	1·1	1·7	1·1	0·9
May 12	25 c.c.	20 %	1·3	2·8	1·4	—
Apr. 30, May 5 and 13	30 c.c.	20 %	2·1	4·2	—	1·8
May 7 and 8	30 c.c.	14 %	2·2	4·5	—	2·4

alcohol in 14 per cent. strength. The numbers of (corrected) mistakes made are quoted in Table XXI, means having been taken when two or more experiments were made under the same conditions. From these values, and from the curves in Fig. 5, it will be seen that the

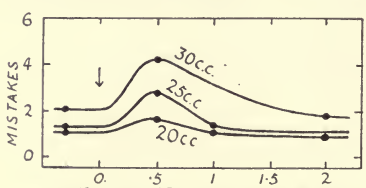

FIG. 5. The Effects of various quantities of Alcohol on N. B. D.

effect of the alcohol was more or less proportional to the quantity consumed. It is impossible to make an accurate comparison, as the number of mistakes made in the control typings, before the alcohol was drunk, was nearly twice as great in the 30 c.c. alcohol experiments as in the others.

In a group of four experiments, in which 40 c.c. of alcohol were taken at 7.0 to 7.30 with food, the effects produced were the following:

Date of Experiment.	Number of mistakes.		
	Shortly before food.	40 min. aft food.	3 hours after food.
Apr. 21	1·9	5·0	1·3
„ 22	1·6	2·2	1·7
„ 23	1·8	3·7	2·8
„ 24	1·9	4·3	1·7
Mean	1·8	3·8	1·9

These effects are about the same as those produced by taking 30 c.c. of alcohol on an empty stomach, and in the light of these and other experiments described subsequently, it appeared that Mr. Dreyer did not respond so differently to alcohol with and without food as most subjects do. In them, as in myself, alcohol is about twice as effective when taken on an empty stomach as when taken with food.

It is well known that individuals vary greatly in their susceptibility to alcohol, and this fact is well brought out by one of the three series of experiments made by a lady, K. D. V. She, like myself, is practically an abstainer, and has been completely so for the last three years. She typed the same passage as myself, and upon the same machine. She typed it five times on each occasion, with about half

TABLE XXII.—*The Effects of 22·3 c.c. Alcohol with Food on K. D. V.*

Normal week.					Alcohol with Food at 7 to 7.30 p.m.				
Date.	At 11.29 a.m.		At 8.54 p.m.		Date.	At 11.26 a.m.		At 8.37 p.m.	
	Typing time.	Mistakes.	Typing time.	Mistakes.		Typing time.	Mistakes.	Typing time.	Mistakes.
Feb. 26	119·6	2·2	136·8	4·0	Mar. 5	113·6	4·2	125·4	5·8
„ 27	124·4	4·3	—	—	„ 6	114·2	2·8	117·2	6·0
„ 28	125·4	3·2	132·0	3·6	„ 7	110·4	4·1	124·8	4·9
Mar. 1	119·6	2·2	131·4	3·9	„ 8	117·0	3·0	122·2	4·2
„ 2	115·4	4·8	129·8	3·0	„ 9	114·6	3·3	123·2	2·6
„ 3	118·4	3·4	125·8	1·6	„ 10	105·4	2·4	123·5	4·9
„ 4	122·0	3·6	130·2	5·1					
Mean ..	120·7	3·4	131·0	3·5		112·5	3·3	122·7	4·7

a minute's rest between the typings. After practising occasionally for five days, she typed for a week under normal conditions at about 11.30 in the morning, and again in the evening at about 9.0 p.m. She then showed a considerable fatigue effect, as her average typing time was 10·3 seconds longer than in the morning, though the number of mistakes made was almost the same. During the next week she took 22·3 c.c. of alcohol (diluted to 150 c.c.) each evening with her dinner between 7.0 and 7.30, or at an average time of about 7.13. This quantity of alcohol was equivalent to the 30 c.c. drunk by myself, as our body weights were 55·3 and 74·4 kgm. respectively. A typing was made at or about 8.37, or 84 minutes after the time at which most of the alcohol was drunk, and from the data in Table XXII it will be seen that the mean typing time was 10·2 seconds slower than at 11.26 a.m., whilst 1·5 more mistakes were made. That is to say, the alcohol caused almost the same increment of mistakes as 30 c.c. of it had done in myself under very similar conditions. However,

K. D. V. said that her subjective sensations of vertigo—which were considerable—had been at a maximum immediately after the meal was over, and had largely disappeared when she did the typing, and there can be no doubt that a great deal of the lack of neuro-muscular co-ordination had disappeared likewise.

In the third week a typing was made at about 11.30 a.m., and immediately after it half the previous quantity of alcohol, or 11·2 c.c. (diluted to 100 c.c.), was drunk. This was upon an empty stomach, as no food had been taken for 3¼ hours. The typing was repeated at an average time of 20 minutes after the alcohol consumption, i.e. it was begun 14 minutes after, and finished 26 minutes after. As can be seen from Table XXIII, the effects were considerable, the number

TABLE XXIII.—*The Effects of 11·2 c.c. Alcohol without Food at 11.40 a.m. on K. D. V.*

Date.	At 11.34 a.m.		At 12 noon.		At 12.45 p.m.	
	Typing time.	Mistakes.	Typing time.	Mistakes.	Typing time.	Mistakes.
Mar. 13	115·8	2·8	118·6	5·9	—	—
,, 14	114·8	2·2	115·4	4·7	112·4	2·1
,, 15	111·2	1·6	113·8	3·2	110·2	2·9
,, 16	113·4	1·7	113·4	2·8	113·2	1·1
,, 17	113·4	3·8	117·0	5·3	113·8	1·9
,, 18	111·2	2·6	115·8	5·4	111·2	2·0
Mean . .	113·3	2·4	115·7	4·5	112·2	2·0

of mistakes being nearly doubled, and the typing time increased 2·5 seconds. A third typing was made at an average time of 65 minutes after the alcohol ingestion, and by then the effects had completely disappeared. In fact, the typing time was 1·1 secs. shorter than in the control experiments, and the mistakes were 0·4 fewer.

It will be realized that K. D. V. was extraordinarily susceptible to the action of alcohol when taken on an empty stomach. The effects appeared to develop more quickly in her than they did in myself, and they certainly passed off more rapidly, though in all probability this was merely the result of the smaller dose taken.

II. The Effect of Pure Alcohol on Neuro-muscular Co-ordination, as shown by the Target Method.

A large number of experiments have been made upon the effect of alcohol on various muscular acts, and many of them have been recorded and discussed at some length by the Advisory Committee.[1]

[1] Cf. *Alcohol: its Action on the Human Organism.* London, 1918.

The experiments fall into three main classes, for they were made on (1) reflex movements, such as the knee-jerk and eye-closing reflex; (2) simple and unskilled movements, such as the speed with which a finger can be moved to and fro, the strength of the finger muscles in raising a load (tested by ergograph), and the speed with which the eyes can be turned towards a fresh object; (3) complex muscular acts, such as hill-climbing and the manipulation of recording apparatus. The Committee concluded that though moderate doses of alcohol (40 c.c. or less) had very little effect on the performance of simple muscular acts requiring no skill, they distinctly impaired the performance of skilled acts. However, the skilled muscular acts investigated were not well defined, nor was the effect of alcohol upon them measured quantitatively, so I thought it to be of interest to make some further observations. The method employed was a very simple one, which I have designated the 'target' method.

The Target Method. Upon squared paper, preferably ruled in millimetres, rows of ten ink dots are made at distances of two centimetres or more apart. The paper is pinned on to a nearly vertical drawing-board, and at such a level that the uppermost spots are approximately at shoulder height. The subject of experiment stands squarely facing the board, at such a distance that he can just reach and prick the paper with the sharp pointed instrument (e.g. a small awl) held in his hand, when he stretches out to arm's length. He has a few preliminary trials to get his correct distance, and this, once ascertained, should be fixed by drawing a chalk mark on the floor, against which he 'toes the line'. Then the subject puts his hand against his chest, and when he has steadied himself, he extends his hand at a moderate speed and tries to prick the uppermost spot on the left-hand side of the paper. He withdraws his hand quickly until it touches his chest, and then extends it again, and pricks the next spot below. He continues this process at a steady rate, pricking each of the ten spots in succession, and then he starts working upwards on the next row of ten spots, till he finally arrives at the level at which he started. This pricking of the 20 spots usually takes 50 to 60 seconds, and the time required was found to remain very steady throughout a series of experiments, even when no mechanical method was adopted to make it constant. After the first few experiments, however, I followed Dr. MacDougall's suggestion of pricking the paper synchronously with the ticks of a metronome, which gave 20 double ticks in 55 seconds. As a precaution against error, the time of each experiment was always taken by means of a stop-watch, held in the left hand of the subject.

The distance of each prick from its spot was subsequently measured to the nearest millimetre, and a mean of the 20 distances taken. As a rule the distance was about 2 mm., and it could be read off at a glance. The sheets of paper used had space enough for twelve rows of ten spots each, or were sufficient for six experiments. The pricking experiments were usually repeated at three-minute intervals, and after eight of them had been made, to serve as a normal, the dose of alcohol was taken, and the experiments were continued for an hour at three-minute intervals. Then, for the next hour or less, they were made at six-minute intervals. The chief objection to the method, when

employed on absolutely fresh subjects, lies in the considerable improvement of accuracy in pricking the target which is shown in the course of successive experiments. For instance, four medical students showed an average error of 2·53 mm. in their first experiment, but this dwindled down to 1·70 mm. in their last experiment made 101 minutes later. However, we shall see that it is possible to make an allowance for this improvement. In my own case, doubtless because of considerable practice, there was no improvement of accuracy after the first four experiments, or latterly, after the first two experiments.

TABLE XXIV.—*The Influence of 30 to 60 c.c. Alcohol on Target-pricking Errors.*

Times of experiments.	Volume of alcohol taken at 11.31 a.m.				
	30 c.c.	37·5 c.c.	45 c.c.	52·5 c.c.	60 c.c.
11.8 and 11.11	—	1·63	1·80	2·05	1·87
11.14 and 11.17	—	1·85	1·60	1·70	1·35
11.20 and 11.23	2·09	1·58	1·80	1·82	1·77
11.26 and 11.29	1·93	1·57 (1·67)	1·52 (1·59)	1·73 (1·77)	1·53 (1·62)
11.31	— (1·94)	—	—	—	—
11.34 and 11.37	1·95	1·67	1·43	1·82	1·82
11.40 and 11.43	1·99	2·08	2·47	2·63	1·98
11.46 and 11.49	2·15	2·60	2·75	3·10	2·70
11.52 and 11.55	2·16	2·45	2·75	3·72	3·05
11.58 and 12.1	2·17	2·32 (2·39)	3·20	3·50 (3·41)	4·50
12.4 and 12.7	2·25 (2·17)	2·50	3·25 (2·92)	3·28	3·90 (3·76)
12.10 and 12.13	2·10	2·10	2·65	3·45	3·55
12.16 and 12.19	2·16	2·25	2·75	3·00	3·78
12.22 and 12.25	2·15	2·03	2·33	2·87	2·92
12.28 and 12.31	1·98	1·95	2·57	2·55	2·55
12.37 and 12.43	2·01	1·97	2·50	2·08	2·48
12.49 and 12.55	1·98	1·85	2·18	2·40	1·95
1.1 and 1.7	1·94	1·92	2·00	1·90	2·20
1.13 and 1.19	1·89	1·80	1·80	1·92	1·82
1.25 and 1.31	1·83	1·60	1·82	1·70	1·70
Increased error due to alcohol	12 %	43 %	84 %	93 %	132 %

The effects of various quantities of alcohol upon the accuracy with which the target was pricked are recorded in Table XXIV, and are reproduced in Fig. 6. The alcohol was taken at about 11.30 a.m., or rather more than three hours after food was last consumed. It was diluted with slightly warmed water to 300 c.c., or the concentration varied from 10 per cent. in the 30 c.c. experiments to 20 per cent. in the 60 c.c. experiment, except in three of the six experiments with 30 c.c. alcohol. These six experiments were made at different times of the year from the rest (viz. in May, June, and November), and will be referred to again later. The single experiments with larger doses were made at intervals of two or three days in December. In order to get more even results, the mean target-pricking errors of each consecutive pair of experiments have been averaged, but even then the irregularities are somewhat considerable. Hence, in plotting

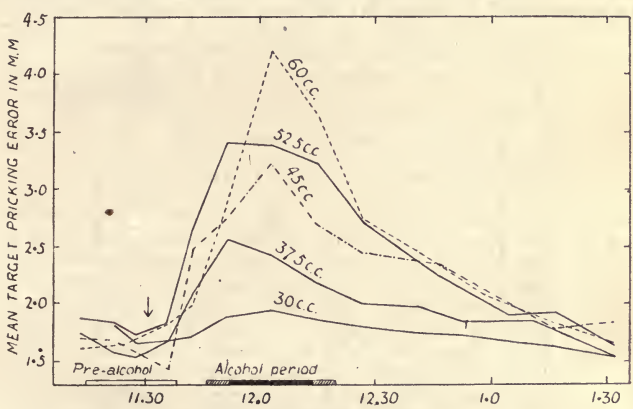

FIG. 6. The Effects of various quantities of Alcohol on Target-pricking Errors.

out these data in Fig. 6, some more of the consecutive results have been averaged. To get a normal, against which the alcohol effect could be compared, the errors observed in the three double experiments immediately before the alcohol, and in the one double experiment after it (i.e. before the alcohol began to exert its influence), have been averaged. Against this normal have been compared the average errors observed in the five consecutive experiments in which the alcohol produced the greatest lack of co-ordination. The incidence and duration of these normal and alcoholic periods are shown at the bottom of Fig. 6. It will be seen that even in the half-hour for which the alcohol effect was averaged there was no constancy, but a gradual waxing to a maximum, followed by a gradual waning. However, a more reliable result is obtained by averaging the alcohol effects over a half-hour period than over a shorter interval such as ten minutes.

From Table XXIV it will be seen that whilst the consumption of 30 c.c. of alcohol increased the target-pricking error only by

12 per cent., 37·5 c.c. increased it 43 per cent., or more than three times as much. With equal increments of 7·5 c.c. to the quantity of alcohol consumed, the error increased at the same rapid rate, for it will be seen from Fig. 7 that the relationship between the quantity of alcohol and the error induced is practically a linear one. No experiments were made with smaller doses of alcohol than 30 c.c., but if the straight line joining the experimental values be produced, it cuts the abscissa at 27 c.c., or indicates that such a dose would have induced no extra lack of co-ordination whatever. In the light of the previously recorded experiments on typewriting, we may conclude that the curve is not strictly linear when it approaches the abscissa, but is curved in somewhat the manner indicated by the dotted line. In any case, smaller quantities of alcohol than 30 c.c. would have produced so slight a diminution of co-ordination as scarcely to be measurable. We may say, therefore, that above

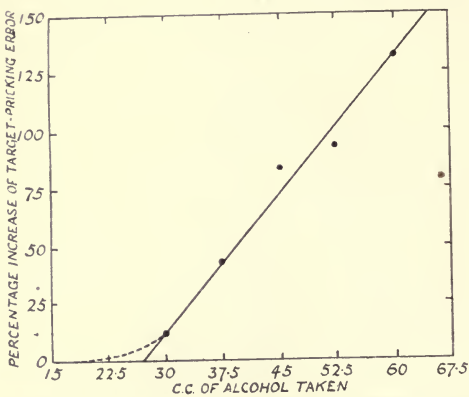

Fig. 7. Relationship between Target-pricking Error and quantity of Alcohol taken.

a certain minimum, *the adverse influence of alcohol on neuro-muscular co-ordination varies in arithmetical progression with the quantity taken.* This conclusion is confirmed by observations made by a totally different method. Sherrington and Sowton[1] showed that if a beating cat's heart were perfused with warm oxygenated salt solution containing a constant amount of chloroform, the height of the beat rapidly sank, but after a minute or two it attained an equilibrium level, and continued to beat unchanged for as long as twenty minutes. I made similar experiments with tortoise hearts,[2] which were perfused with cold oxygenated salt solution containing 1 to 4 per cent. of ethyl alcohol. As an average of eight experiments, I found that whilst 1 per cent. of alcohol depressed the level of the heart-beat 13 per cent., 2 per cent. depressed it 40 per cent., and 4 per cent. depressed it 83 per cent. These three values are almost exactly in linear proportion to the

[1] Sherrington and Sowton, *Thompson Yates and Johnston Laboratories Reports*, vol. v Pt. 1, 1903.

[2] Vernon, *Journ. Physiol.* vol. 41, p. 194, 1910.

concentration, or the height of the heart-beat varied directly with the concentration of the alcohol. Experiments with eight other alcohols gave a similar linear relationship between height of beat and concentration of alcohol.[1]

The maximum dose of 60 c.c. of alcohol, taken on an empty stomach, produced considerable subjective effects. I felt extremely dizzy and sleepy, and, about 1½ hrs. after taking the dose, vomited slightly. I could still carry out the necessary manipulations of the experiment without much difficulty, and could walk quite straight along a chalk line marked on the floor, though this required a little effort. Still, a larger dose than that taken would probably have induced overpowering somnolence and inability to conduct the experiment.

It should be mentioned that, in order to make the mean result obtained in the 30 c.c. alcohol experiments conform to the experiments with 37·5 to 60 c.c. alcohol, which were carried out months later, the base line of normality on which it has been drawn in Fig. 6 has been arbitrarily lowered to the average normal level attained in these latter experiments.

III. The Effects of Wines and Spirits.

Comparison with the Effects of Pure Alcohol.

It is generally assumed that the influence of alcoholic liquids depends almost entirely upon the ethyl alcohol contained in them. If this assumption were valid, it would follow that the toxic action of pure alcohol, wines, spirits, and beer, if diluted to equal alcoholic strength, would be practically the same. As we have no exact proof of the validity of the assumption, it was thought to be of interest to make comparisons between the effects of alcohol and of various alcoholic liquids by means of the typewriting and neuro-muscular co-ordination tests.

Comparative experiments were made by Mr. Dreyer upon himself by the typing method. In one series, 35 c.c. of alcohol, diluted to

Table XXV.—*The Effects of 35 c.c. Alcohol with Food on N. B. D.*

Dates of experiments.	Alcoholic liquid taken.	Concentration.	Typing mistakes made			
			Shortly before alcohol.	40 mins. after.	1 hr. after.	2 hrs. after.
May 30	pure alcohol	10·2 %	0·6	1·9	1·5	0·8
June 4 and 5	whisky	10·2	0·4	1·2	1·4	0·5
May 29 and June 3	claret	10·2	0·6	1·3	1·0	0·7
May 23	pure alcohol	20	0·4	2·4	2·0	1·1
May 22 and 26	whisky	20	0·9	2·4	1·7	0·8

[1] Vernon, *Journ. Physiol.* vol. 43, p. 325, 1911.

10·2 per cent. strength, were taken with food (at 7.0 to 7.30 p.m.) in the form of whisky, claret, and as pure alcohol. From Table XXV it will be seen that two experiments were made with whisky and with claret, and one with alcohol. The mistakes made in these experiments have been corrected for variable speed of typing, and averaged, and

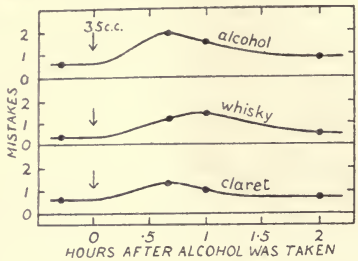

FIG. 8. The Effects of various Alcoholic Liquids on N.B.D.

the average results are shown in Fig. 8. It will be seen that the pure alcohol produced a slightly greater effect than the whisky, whilst the claret produced a slightly less effect. Another series of experiments was made about nine days earlier, with the alcohol in 20 per cent. concentration instead of 10·2 per cent. These results are not strictly comparable with the series just mentioned, as the subject showed some diminution of susceptibility throughout his experimental period. However, they are comparable amongst themselves, as are the previous series, as they were made at about the same time. They likewise show that 35 c.c. of pure alcohol, taken with food, had rather more influence than 35 c.c. in the form of whisky.

Another series of experiments was made a fortnight after the first of the two series just mentioned. Four experiments were made with 20 c.c. of alcohol, or its equivalent in the form of claret and whisky, and four with 30 c.c. of alcohol, or its equivalent in claret. In every

TABLE XXVI.—*The Effects of 20 and 30 c.c. Alcohol, without Food, on N. B. D.*

Dates of experiments.	Alcoholic liquid taken.	Typing mistakes made			
		Shortly before alcohol.	½ hr. after.	1 hr. after.	2 hrs. after.
June 12 and 16	pure alcohol (20 c.c.)	0·3	0·9	0·5	0·2
June 19 to June 17	whisky ,,	0·2	0·6	0·1	0·1
	claret ,,	0·2	0·6	0·2	0·3
June 11 and 13	pure alcohol (30 c.c.)	0·4	1·1	0·4	0·3
June 14 and 15	claret ,,	0·3	1·3	0·5	0·3

experiment the alcohol was taken in 10·2 per cent. solution at about 4.30 p.m., or three hours after food. From Table XXVI it will be seen that 20 c.c. of pure alcohol produced rather more effect than its equivalent as whisky and claret, whilst on the other hand 30 c.c. of alcohol produced rather less effect than its equivalent as claret. On an average, therefore, the alcohol and claret had about the same effect.

On comparing these foodless experiments with the preceding series of food experiments, it will be seen that 30 c.c. of alcohol on an empty stomach produced, if anything, less effect than 35 c.c. on a full stomach. Such a small influence of food is contrary to the results obtained with all the other subjects of experiment, and one must attribute the apparent contradiction, at least in part, to Mr. Dreyer's diminishing susceptibility.

The smaller response of Mr. Dreyer to claret and whisky than to pure alcohol is unexpected, and does not agree with the neuro-muscular co-ordination tests to be described. Doubtless different individuals vary in their response, and one may conclude that in any case the difference between pure alcohol and alcoholic liquids of equal alcoholic strength is a small one.

The neuro-muscular co-ordination tests upon myself were made by the target method in three groups of six experiments each. In each group I tested the effects of 30 c.c. of alcohol, taken (1) as pure alcohol in 10·2 per cent. and 40 per cent. strength,

TABLE XXVII.—*Effects of 30 c.c. Alcohol on Target-pricking Errors.*

Times of experiments.	Control experiments.	10·2 % alcohol.	40 % alcohol.	10·2 % brandy.	37 % brandy.	10·2 % claret.	Means of alcohol experiments.
4.49 and 52	1·85	2·17	2·00	2·00	2·05	2·05	2·05
4.55 and 58	1·87	1·98	1·88	1·68	1·73	1·73	1·80
5·0	no alcohol	alcohol	alcohol	alcohol	alcohol	alcohol	—
5.3 and 6	1·73	2·00	1·90	1·75	1·75	1·60	1·80
5.9 and 12	1·73	2·15	1·83	1·97	1·85	1·70	1·90
5.15, 18, 21 and 24	1·80	2·28	2·03	2·00	2·20	1·95	2·09
5.27, 30, 33 and 36	1·79	2·33	2·08	1·89	2·00	2·04	2·07
5.39, 42, 45 and 48	1·81	2·30	1·96	1·96	2·06	2·11	2·08
5.51, 54, 57 and 6.0	1·74	2·22	1·91	1·91	1·93	2·01	2·00
6.6 and 12	1·70	2·15	1·87	1·63	1·95	1·95	1·91
6.18 and 24	1·87	2·27	1·70	1·70	1·73	1·83	1·85
6.30 and 36	1·75	2·10	1·78	1·68	1·75	1·95	1·85
6.42 and 48	1·75	2·00	1·77	1·68	1·77	1·73	1·79
6.54 and 7.0	1·68	2·05	1·60	1·77	1·68	1·85	1·79

(2) as brandy, taken in 10·2 per cent. and 37 per cent. strength, (3) as claret, taken in 10·2 per cent. strength. Also a control experiment was included. The experiments of each group were made on consecutive days, the order in which they were made being changed in the different groups so as to eliminate any possible influence of diminishing susceptibility. In the series of

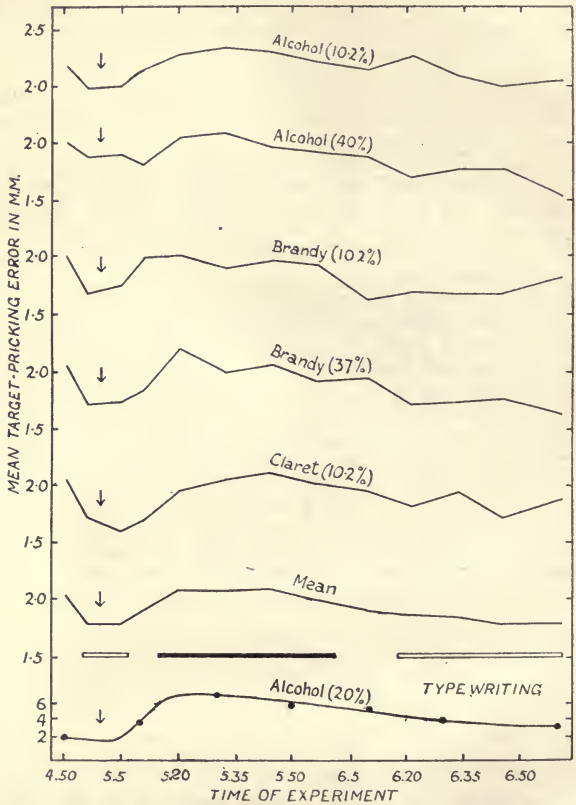

FIG. 9. The Effects of various Alcoholic Liquids on Target-pricking Errors.

experiments made in May and June, the alcohol was drunk at about 5.0 p.m., or about 3 hours 15 minutes after food was last taken. In the November experiments it was drunk at about 11.30 a.m., or 3 hours 5 minutes after food, but this slightly shorter interval made no appreciable difference in the result. The records given in Table XXVII show, not the individual results, but the means of each set of three experiments, with a further averaging of these

means in groups of two or four. That is to say, each value quoted represents the mean of 120 or 240 attempts to prick the target. These grouped values are reproduced in Fig. 9, where it will be seen that they yield fairly regular curves. Only four experiments at three-minute intervals were made before drinking the alcohol, and the first two of these must be ignored because of the increased error due to lack of practice. However, the effects of the alcohol did not appreciably develop for the first six minutes after it was drunk, so one can take the mean of the two experiments immediately before drinking the alcohol, and the two immediately after, as an index of the target-pricking errors made in absence of alcohol. It will be seen that the errors increased to a maximum about 20 to 40 minutes after the alcohol, and then gradually dwindled to the pre-alcohol average, which they practically attained within two hours. At the bottom of the figure is given the mean of all the fifteen alcohol experiments, and also, on a corresponding scale, the mean of the two typewriting experiments in which 30 c.c. of alcohol were taken in 20 per cent. strength (cf. Table XV). It will be seen that the general contour of the two curves is similar, for in each of them the maximum alcohol effect was attained after about 30 minutes, and had nearly disappeared after 2 hours.

In order to obtain a satisfactory numerical measure of the effect produced on neuro-muscular co-ordination by the various alcoholic liquids, it was thought best to compare the mean errors observed in the 46 minutes (between 5.15 and 6.1) when the alcohol effect was greatest with the mean errors observed in the 12 minutes (between 4.55 and 5.7) before the effect came on, and the 43 minutes (between 6.18 and 7.1) when it had largely disappeared. These periods of comparison are shown under the mean curve in Fig. 9. The numerical effects are recorded in Table XXVIII, and we see that, on an average, the dilute

TABLE XXVIII.—*Mean Target-pricking Errors observed when taking Various Alcoholic Liquids.*

30 c.c. alcohol taken in the form of	Mean error for 12 min. before and 43 min. after alcohol.			Mean error for 46 min. at height of alcohol effect.			% increase of error due to alcohol.			
	May.	June.	Nov.	May.	June.	Nov.	May.	June.	Nov.	Mean.
10·2 % alcohol	1·89	2·25	2·06	2·17	2·38	2·28	15	6	11	11
40 % „	1·62	1·78	1·91	1·83	2·10	2·05	13	18	7	13
Brandy containing 10·2 % alcohol	1·69	1·72	1·72	1·96	1·97	1·89	16	15	10	14
Brandy containing 37 % alcohol	1·70	1·97	1·54	2·05	2·26	1·82	21	15	18	18
Claret containing 10·2 % alcohol	1·65	2·15	1·53	2·02	2·29	1·81	22	7	18	16
Mean	1·71	1·97	1·75	2·01	2·20	1·97	17	12	13	14

alcohol caused 11 per cent. increase of target-pricking error, whilst the 40 per cent. alcohol caused a 13 per cent. error. The brandy was distinctly more effective, especially when taken neat, as in this form it caused an 18 per cent. error. Claret came midway between dilute and neat brandy, as it caused a 16 per cent. error. The mean error induced by alcoholic liquors was 16 per cent., as compared with 12 per cent. for pure alcohol of similar concentration. Hence there can be no doubt that in my own case brandy and claret were distinctly more toxic than pure alcohol.

The mean values obtained in the three control experiments are recorded in Table XXVII, and it will be seen that the target-pricking error remained nearly constant throughout the 132 minutes for which the experiments lasted. It was not possible to use these control values as a normal base line in the various alcohol experiments, for 'normality' varies appreciably from day to day. For instance, it happened that on the days when 10·2 per cent. alcohol was taken the average target-pricking error was considerably higher than usual.

The other subjects of experiment were five in number, viz. Messrs. T. H. Cathrall, N. B. Dreyer, M. H. MacKeith, D. B. Pauw, and another. They were all medical students, aged 21 to 24, and all but the anonymous student were, and always had been, of very temperate habits, though they were not abstainers. I wish to express my thanks to them for the care and enthusiasm with which they carried out the somewhat tedious experiments. The method of experiment was similar to that employed by myself, except that they did eight experiments at three-minute intervals before taking the alcohol, and twenty-six experiments after it, likewise at three-minute intervals, so in their case the whole experiment lasted 102 minutes. Four of the subjects of experiment took, on one occasion, 30 c.c. of alcohol diluted to 10·2 per cent. strength, and on another occasion 294 c.c. of claret, which likewise contained 30 c.c. of alcohol in 10·2 per cent. strength. The alcohol

TABLE XXIX.—*The Influence of 30 c.c. Alcohol on the Target-pricking Errors of Four Men.*

Time of experiments.	Pure alcohol.	Claret.	Time of experiments.	Pure alcohol.	Claret.
4.37 and 4.40	2·92	2·11	5.27 and 5.30	2·55	2·30
4.43 and 4.46	2·70	2·18	5.33 and 5.36	2·47	2·36
4.49 and 4.52	2·22	1·90	5.39 and 5.42	2·54	2·29
4.55 and 4.58	2·32	1·68	5.45 and 5.48	2·17	2·18
5.0	alcohol	alcohol	5.51 and 5.54	2·05	1·70
5.3 and 5.6	1·96	1·57	5.57 and 6.0	1·90	1·85
5.9 and 5.12	2·14	1·91	6.3 and 6.6	1·90	1·85
5.15 and 5.18	2·23	1·98	6.9 and 6.12	1·91	1·73
5.21 and 5.24	2·19	2·09	6.15 and 6.18	1·77	1·63

was always taken three hours, or rather more, after food, and the order in which the experiments were made was reversed in two of the four subjects, so as to equalize the effects of practice. The mean results of the experiments are recorded in Table XXIX, and these results are reproduced graphically in Fig. 10. It will be seen that the effects were distinctly greater than in myself, but no exact numerical comparison is possible because of the considerable improvement of skill shown by the students during the course of the experiments. Whilst their average target-pricking error in the last two experiments was only 1·70 mm., or rather less than my own (1·79 mm.), it was 2·52 mm. in the first two experiments, as against a value of 2·05 mm. in myself. The errors which probably would have been made if no

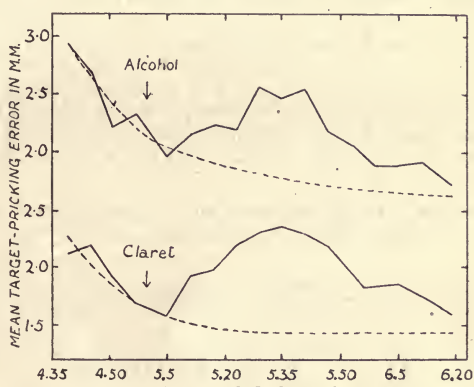

Fig. 10. The Effects of Alcoholic Liquids on the Target-pricking Errors of Four Men.

alcohol had been taken are drawn as dotted lines through the respective curves. These dotted lines are not the same for the two curves, but a reference to the data in Table XXIX will show that it would be incorrect to make them so. It happened that on the days of the experiments with pure alcohol the subjects made considerably greater target-pricking errors than on the days of the claret experiments. In order to obtain a numerical comparison of the effects of the pure alcohol and the claret, one can compare the mean error made at the height of the alcohol effect (viz. from 5.27 to 5.43) with that made in the last 16 minutes of the experiments, when most of the alcohol effect had worn off. The increment of error works out at 35 per cent. in the pure alcohol experiments, and 33 per cent. in the claret experiments. If, on the other hand, the basis of comparison be taken as from 5.3 to 5.13, or just before much alcohol effect had developed, the increment of error works out at 23 per cent. in the pure alcohol experiments, and 33 per cent. in the claret experiments. Probably, therefore, we may conclude that the claret was slightly more toxic than the alcohol.

The four students varied distinctly in susceptibility, one of them (Mr. Dreyer, on whom numerous typewriting experiments have been

recorded) being more susceptible than the average, and one of them less susceptible, whilst the other two were about the average. The experiments made with the fifth student are not included with those made on the other four, as they call for special mention. This student had been stationed for three years, 1915–17, on the West Coast of Africa, and, by reason of the trying climate, had got into the habit of drinking rather heavily. From data which he gave me as to the amount of his mess bills, and the price of whisky, I was able to calculate that he drank between a half and two-thirds of a bottle of whisky a day, on an average, or about 170 c.c. of pure alcohol. His body weight is 10 stone (64 kgm.). He did not start drinking till 11.0 a.m., and took most of the alcohol between meals, and very little of it with food. When he returned to England he resumed temperate habits, and now drinks about three pints of beer a week. He felt some craving for more alcohol for the first three months after his return, but he has no desire whatever for it now. When this student took the usual 30 c.c. of diluted alcohol and 294 c.c. of claret, he showed no increase of target-pricking error whatever, as can be gathered from the upper curve shown in Fig. 11 which records the mean of the two experiments, and the data in Table XXX. A week after these

TABLE XXX.—*The Effect of 30 to 60 c.c. Alcohol on the Target-pricking Errors of a rather Heavy Drinker.*

Times of experiments.	30 c.c. alcohol or claret.	Whisky containing 45 or 60 c.c. alcohol.	Times of experiments.	30 c.c. alcohol or claret.	Whisky containing 45 or 60 c.c. alcohol.
11.37 and 11.40	3·18 } 3·32	2·68	12.33 and 12.36	2·00	1·38
11.43 and 11.46	3·47 }	2·50	12.39 and 12.42	2·00	1·28
11.49 and 11.52	2·98	2·32	12.45 and 12.48	1·85	1·30
11.55 and 11.58	2·92	2·20	12.51 and 12.54	1·95	1·35
12.0	alcohol	alcohol	12.57 and 1.0	1·98	1·35
12.3 and 12.6	2·87 } 2·54	1·83	1.6	2·02	1·15
12.9 and 12.12	2·20 }	1·55	1.12	2·07 } 1·98	1·18
12.15 and 12.18	2·22	1·45	1.18	1·90 }	1·27
12.21 and 12.24	2·13	1·33	1.24	1·90	1·22
12.27 and 12.30	2·07	1·37			

experiments were made, he carried out another experiment in which he drank 45 c.c. of alcohol in the form of whisky diluted to 20 per cent. alcoholic strength. Two days later he made another experiment in which he drank 60 c.c. of alcohol in the form of whisky diluted to 27 per cent. strength. The whisky was taken three hours after food or practically on an empty stomach, but neither dose had a definite effect on neuro-muscular co-ordination. The lower curve in Fig. 11 is

a mean of the two whisky experiments, and though it may be taken to indicate a slight increase of target-pricking error 30 to 60 minutes after drinking the alcohol, the increase is so slight as to be within the limits of experimental error.

The student said that he experienced no subjective sensations of vertigo whatever after drinking the whisky, and certainly his conversation showed no signs of any effect. Hence it follows that a dose of alcoholic liquid which would have induced a state not far removed

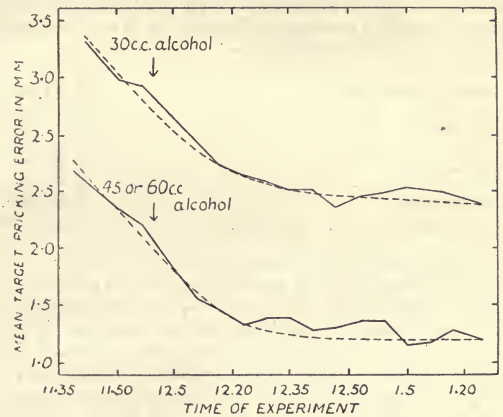

FIG. 11. The Effects of Alcoholic Liquids on the Target-pricking Errors of a rather Heavy Drinker.

from intoxication in myself and in three of the other four medical students, was practically without effect upon him. Apparently his acquired immunity to alcohol had persisted unchanged for a year since he gave up heavy drinking.

Other Experiments upon the Effects of Wine and Spirits.

As it is important to determine whether the adverse effects of moderate quantities of alcoholic liquids are general, Dr. W. C. Sullivan and Capt. M. Greenwood, members of the Advisory Committee, were good enough to make a series of experiments upon themselves and their assistants, and to furnish me with an account of these experiments.

The detailed information here adduced, of the experiments on subjects K., B., and S., is quoted from Dr. Sullivan's account, but the comments on it, which are given at the end, are my own.

Capt. Greenwood's experiments are described and discussed by himself, except that I have, with his permission, abbreviated some of his Tables of figures.

Dr. W. C. Sullivan's Experiments.

"*Subject K.* The method adopted was to type ten times an official note of 54 words, totalling 250 letters, so that with spacing, changing key, and restarting line, the typing of each note involved 315 movements. The time taken for each complete typing was marked with a stop-watch. All typing was done as rapidly as the typist felt to be consistent with general accuracy. The subject is a skilled typist.

The daily routine was as follows:—

Breakfast finished	8.45 a.m.
1st typing	10.0 a.m.
2nd typing	12.15 p.m.
Lunch finished	1.30 p.m.
3rd typing	2.15 p.m.
Tea finished	3.45 p.m.
4th typing	4.0 p.m.

The alcohol on an *empty* stomach was taken at 11.45 a.m., or half an hour before the second typing, whilst the alcohol on a *full* stomach was taken with or immediately after lunch, or three-quarters of an hour before the third typing. The subject did no other typing during the experiment. Being a skilled typist, she did not practise the letter before starting the experiment. The test recorded here lasted for 29 days. For 5 days, viz. from June 17 to 21, the tests were done without alcohol, and again for 4 days at the end, from July 23 to 26. The following quantities of alcoholic liquids were taken:

From June 24 to 28, 13 oz. claret (= 36·7 c.c. alcohol) were taken with lunch.

July 1 to 5, 13 oz. claret (= 36·7 c.c. alcohol) were taken on empty stomach at 11.45 a.m.

July 9 to 12, and 15, 4 oz. port (= 22·0 c.c. alcohol) were taken with lunch.

July 16 to 19, and 22, 4 oz. port (= 22·0 c c. alcohol) were taken on empty stomach at 11.45 a.m.

The results are shown in Tables XXXI to XXXVI. The figures entered opposite each day indicate—in the time column—the average time (in seconds) taken to type the note at each of the several séances of the day; and the figures under 'errors' show similarly the average number of mistakes made in typing the note at each of the séances.

The subject is a moderate drinker, and is not susceptible to alcohol. She found the claret rather too much in bulk, and had great difficulty in drinking the second glass. She felt slightly irritable all the afternoon. At the end of the week, she felt markedly tired. The port caused her no discomfort whatever.

TABLE XXXI.—*First Week—No Alcohol.*

	Time.				*Errors.*			
	10 *a.m.*	12.15 *p.m.*	2.15 *p.m.*	4 *p.m.*	10 *a.m.*	12.15 *p.m.*	2.15 *p.m.*	4 *p.m.*
June 17	53·2	49·7	49·5	46·2	0·5	0·3	0·3	0·1
,, 18	48·8	47·6	48·4	44·2	0·1	0·6	0·7	0·3
,, 19	46·2	45·5	45·5	45·0	0·3	0·0	0·6	0·4
,, 20	44·2	44·2	43·2	45·0	0·1	0·1	0·0	0·8
,, 21	43·4	43·0	44·0	42·6	0·3	0·1	0·6	0·2
Weekly average	47·2	46·0	46·1	44·6	0·26	0·22	0·44	0·36

TABLE XXXII.—*Second Week—Claret after Lunch.*

	Time.				*Errors.*			
	10 *a.m.*	12.15 *p.m.*	2.15 *p.m.*	4 *p.m.*	10 *a.m.*	12.15 *p.m.*	2.15 *p.m.*	4 *p.m.*
June 24	44·0	44·1	47·6	48·0	0·4	0·1	1·3	1·3
,, 25	43·5	42·1	43·8	43·3	0·1	0·5	0·6	0·0
,, 26	42·7	43·4	45·4	44·2	0·1	0·2	0·8	0·5
,, 27	42·7	42·2	44·8	40·7	0·6	0·2	1·1	0·5
,, 28	42·6	43·2	45·9	42·1	0·3	0·4	1·1	0·6
Weekly average	43·1	43·0	45·5	43·7	0·30	0·28	0·98	0·58

TABLE XXXIII.—*Third Week—Claret before Lunch.*

	Time.				*Errors.*			
	10 *a.m.*	12.15 *p.m.*	2.15 *p.m.*	4 *p.m.*	10 *a.m.*	12.15 *p.m.*	2.15 *p.m.*	4 *p.m.*
July 1	41·9	49·7	47·6	42·4	0·5	3·6	2·2	0·4
,, 2	40·8	45·7	45·2	43·9	0·4	1·7	0·3	0·7
,, 3	40·9	44·9	44·9	41·7	0·2	2·5	1·2	0·5
,, 4	41·9	48·8	47·1	44·4	0·7	2·8	1·0	0·3
,, 5	42·4	42·7	45·6	42·9	0·3	1·4	1·5	1·4
Weekly average	41·6	46·4	46·1	43·1	0·42	2·40	1·24	0·66

TABLE XXXIV.—*Fourth Week—Port after Lunch.*

	Time.				*Errors.*			
	10 *a.m.*	12.15 *p.m.*	2.15 *p.m.*	4 *p.m.*	10 *a.m.*	12.15 *p.m.*	2.15 *p.m.*	4 *p.m.*
July 9	41·4	41·9	44·0	42·2	0·4	0·7	0·9	0·9
,, 10	42·5	42·0	41·2	39·7	0·7	0·5	0·5	0·5
,, 11	40·3	48·9	42·3	40·9	0·6	0·9	0·3	0·3
,, 12	40·6	41·1	42·5	41·1	0·4	0·8	0·4	0·5
,, 15	41·8	41·8	42·3	40·0	0·1	0·6	0·5	0·5
Weekly average	41·3	43·1	42·5	40·8	0·44	0·70	0·52	0·54

TABLE XXXV.—*Fifth Week—Port before Lunch.*

	Time.				*Errors.*			
	10 *a.m.*	12.15 *p.m.*	2.15 *p.m.*	4 *p.m.*	10 *a.m.*	12.15 *p.m.*	2.15 *p.m.*	4 *p.m.*
July 16	41·6	42·1	42·7	40·2	0·3	0·7	0·7	0·0
,, 17	40·8	43·1	40·6	41·5	0·6	1·3	0·7	0·0
,, 18	41·6	43·1	43·6	40·5	0·5	1·4	0·5	0·4
,, 19	41·9	44·2	44·5	40·0	0·6	2·0	0·5	0·4
,, 22	43·1	44·7	42·3	40·9	0·5	1·9	0·4	0·6
Weekly average	41·8	43·4	42·7	40·6	0·50	1·46	0·56	0·28

TABLE XXXVI.—*Sixth Week—No Alcohol.*

	Time.				*Errors.*			
	10 *a.m.*	12.15 *p.m.*	2.15 *p.m.*	4 *p.m.*	10 *a.m.*	12.15 *p.m.*	2.15 *p.m.*	4 *p.m.*
July 23	42·9	41·6	43·3	41·4	0·6	0·5	0·4	0·3
,, 24	42·5	42·8	43·4	42·2	0·2	0·2	0·2	0·9
,, 25	40·5	42·9	41·6	41·5	0·2	0·2	0·1	0·3
,, 26	42·7	40·1	43·2	41·7	0·3	0·2	0·0	0·5
Weekly average	42·1	41·9	42·9	41·7	0·32	0·27	0·17	0·50

Subject B. The method adopted was to type a proverb 100 times at each sitting, in groups of 10 sets of the proverb. The proverb consisted of 6 words, totalling 28 letters, so that with spacing, changes of key, and restarting line, the typing of each group involved 344 movements. The time taken for each complete group was marked with a stop-watch. All typing was done as rapidly as the typist felt to be consistent with speed and accuracy. The subject is a skilled typist.

The daily routine was as follows:—

Breakfast finished	9.0 a.m.
1st typing	10.0 a.m.
2nd typing	12.40 p.m.
Lunch finished	2.0 p.m.
3rd typing	2.45 p.m.
Tea finished	4.0 p.m.
4th typing	4.30 p.m.

The alcohol on an *empty* stomach was taken at 12.10 p.m., or half an hour before the second typing, whilst the alcohol on a *full* stomach was taken with or immediately after lunch, or three-quarters of an hour before the third typing. The subject did her ordinary work during the tests. She practised the test for a week before starting the experiment. The tests recorded here lasted over 22 days, and were carried out in the following order:

From June 3 to 7, no alcohol was taken.

June 10 to 14, 13 oz. claret (=36·7 c.c. alcohol) were taken with lunch.

June 18 and 19, *July 18*, 4 oz. sherry (=22 c.c. alcohol) were taken with lunch.

Aug. 12, *13*, *15*, *21*, *and 26*, 4 oz. sherry were taken on empty stomach at 12.10 p.m.

Aug. 29 and 30, *Sept. 2 and 3*, no alcohol was taken.

The subject is practically an abstainer, and is very susceptible to alcohol. She found difficulty in drinking the claret on account of its bulk, but the sherry was less objectionable. Both doses caused severe headache and nausea. The results are shown in Tables XXXVII to XLI.

TABLE XXXVII.—*First Group—No Alcohol.*

	Time.				*Errors.*			
	10 *a.m.*	12.40 *p.m.*	2 45 *p.m.*	4.30 *p.m.*	10 *a.m.*	12.40 *p.m.*	2.45 *p.m.*	4.30 *p.m.*
June 3	55·0	53·9	53·9	53·6	2·2	0·9	1·9	1·5
„ 4	51·7	53·5	51·1	53·3	2·3	1·9	1·6	3·4
„ 5	47·7	48·9	48·1	47·5	2·8	3·4	2·8	2·9
„ 6	46·1	49·1	46·6	47·7	2·0	4·8	2·5	1·6
„ 7	48·1	48·8	47·8	45·6	1·4	1·1	2·9	1·7
Average	49·7	50·8	49·5	49·5	2·14	2·42	2·34	2·22

TABLE XXXVIII.—*Second Group—Claret after Lunch.*

	Time.				*Errors.*			
	10 *a.m.*	12.40 *p.m.*	2.45 *p.m.*	4.30 *p.m.*	10 *a.m.*	12.40 *p.m.*	2.45 *p.m.*	4.30 *p.m.*
June 10	47·3	46·5	49·0	46·6	1·9	1·5	4·5	4·0
,, 11	43·4	47·8	46·6	47·9	2·3	3·9	3·3	3·2
,, 12	44·8	45·2	45·2	44·9	3·8	2·8	5·5	7·0
,, 13	44·4	45·1	46·3	45·4	1·7	2·7	6·0	5·0
,, 14	44·5	43·8	44·9	42·4	4·1	4·2	6·0	3·4
Average	44·9	45·7	46·4	45·4	2·76	3·02	5·06	4·52

TABLE XXXIX.—*Third Group—Sherry after Lunch.*

	Time.				*Errors.*			
	10 *a.m.*	12.40 *p.m.*	2.45 *p.m.*	4.30 *p.m.*	10 *a.m.*	12.40 *p.m.*	2.45 *p.m.*	4.30 *p.m.*
June 18	43·9	43·8	46·3	42·6	3·4	3·5	3·8	3·3
,, 19	44·2	43·8	43·9	44·1	2·5	2·2	3·1	1·8
July 18	43·7	44·3	42·9	42·4	2·2	2·0	2·7	2·3
Average	43·9	44·0	44·4	43·0	2·70	2·57	3·20	2·47

TABLE XL.—*Fourth Group—Sherry before Lunch.*

	Time.				*Errors.*			
	10 *a.m.*	12.40 *p.m.*	2.45 *p.m.*	4.30 *p.m.*	10 *a.m.*	12.40 *p.m.*	2.45 *p.m.*	4.30 *p.m.*
Aug. 12	44·8	45·4	45·2	43·9	2·0	4·4	2·1	1·9
,, 13	43·8	44·5	42·9	43·3	1·0	2·7	1·3	1·2
,, 15	43·9	46·2	44·7	43·0	1·5	4·1	2·3	1·4
,, 21	43·1	46·2	43·3	41·8	1·2	3·9	2·3	0·7
,, 26	43·7	45·4	43·5	42·2	1·6	3·6	1·7	2·2
Average	43·9	45·5	43·9	42·8	1·46	3·74	1·94	1·48

TABLE XLI.—*Fifth Group—No Alcohol.*

	Time.				*Errors.*			
	10 *a.m.*	12.40 *p.m.*	2.45 *p.m.*	4.30 *p.m.*	10 *a.m.*	12.40 *p.m.*	2.45 *p.m.*	4.30 *p.m.*
Aug. 29	44·3	45·4	45·1	44·0	1·9	1·5	1·6	1·1
„ 30	44·6	44·4	45·2	45·0	1·5	1·3	1·1	0·9
Sept. 2	44·1	44·2	44·4	44·0	1·2	1·4	0·3	0·9
„ 3	47·6	45·6	44·3	45·0	1·7	2·1	0·7	1·3
Average	45·1	44·9	44·7	44·5	1·57	1·57	0·92	1·05

Subject S. The method adopted was to type the alphabet 100 times at each sitting, the typing being done in sets of 10 alphabets, and the time of typing each set being taken with a stop-watch. The unit for calculating error and speed was thus the set of 10 alphabets. A pause of half a minute was made between each set. The subject typed as rapidly as he felt to be consistent with general accuracy. He is an amateur and uses a faulty method of typing, employing only one finger of each hand—viz. the index finger of the right hand, and the middle finger of the left, the latter being used to strike the 9 letters on the left side of the keyboard. This method was originally adopted casually, and has become habitual.

There were 4 typing séances on each day of the test, viz. at 10.30 a.m., 1.0 p.m., 3.30 p.m., and 5.0 p.m. The experiment, of which the results are here summarized, extended over 13 days between the dates of June 5 and June 25. On the first 4 days, no alcohol was taken. On the other 9 days, 2½ oz. brandy (= 26·25 c.c. alcohol) diluted with an equal part of water were taken, either at 12.40 p.m. —i. e. on an empty stomach, 20 minutes before the 1.0 p.m. typing—or at 2.45 p.m.—i. e. after a light lunch, and three-quarters of an hour before the 3.20 typing. Tests on empty stomach and after food were made on alternate dates. The results are shown in Tables XLII to XLIV. The figures entered opposite each date in the time columns indicate the average times (in seconds) taken to type a set of 10 alphabets at each of the several séances of the day; and the figures under 'errors' show similarly the average number of mistakes made in typing the set of alphabets at each of the séances. At the bottom of each Table, the average results are expressed in percentage relation to the record at 10.30 a.m. taken as the normal of the day."

TABLE XLII.—*Period before Commencement of Alcohol Test.*

Date.	*Time.*				*Errors.*			
	10.30 *a.m.*	1 *p.m.*	3.30 *p.m.*	5 *p.m.*	10.30 *a.m.*	1 *p.m.*	3.30 *p.m.*	5 *p.m.*
June 5	72·6	73·9	72·8	72·7	2·3	3·4	2·9	2·8
„ 6	69·3	66·8	68·2	67·4	4·6	2·2	1·9	2·9
„ 7	68·4	66·4	66·4	69·4	3·5	3·6	4·2	3·3
„ 8	66·8	67·7	69·3	67·3	4·0	5·5	5·7	4·1
Average	69·3	68·7	69·2	69·2	3·6	3·7	3·7	3·3
Average percentage result	100	99	100	100	100	103	103	92

TABLE XLIII.—*Alcohol on Empty Stomach.*

$2\frac{1}{2}$ oz. Brandy with Equal Part of Water at 12.40.

Date.	*Time.*				*Errors.*			
	10.30 *a.m.*	1 *p.m.*	3.30 *p.m.*	5 *p.m.*	10.30 *a.m.*	1 *p.m.*	3.30 *p.m.*	5 *p.m.*
June 12	63·2	66·1	66·5	65·4	4·1	6·1	8·2	5·8
„ 14	60·8	64·9	63·2	60·4	3·7	7·8	7·3	6·1
„ 19	60·0	60·1	58·3	60·4	2·9	3·4	3·3	4·2
„ 24	58·4	60·2	57·4	58·7	5·4	7·7	4·0	3·8
Average	60·6	62·8	61·3	61·2	4·02	6·25	5·70	4·97
Average percentage result	100	104	101	101	100	155	142	124

TABLE XLIV.—*Alcohol after Food.*

$2\frac{1}{2}$ oz. Brandy with Equal Part of Water at 2.45.

Date.	*Time.*				*Errors.*			
	10.30 *a.m.*	1 *p.m.*	3.30 *p.m.*	5 *p.m.*	10.30 *a.m.*	1 *p.m.*	3.30 *p.m.*	5 *p.m.*
June 11	68·1	68·8	70·3	67·3	5·9	4·9	5·2	5·2
„ 13	61·4	64·4	62·2	65·8	2·9	5·6	6·1	7·2
„ 17	62·3	59·9	62·4	62·6	5·8	4·1	5·9	4·2
„ 21	59·3	58·3	59·5	59·8	4·2	2·9	3·1	2·4
„ 25	56·6	56·2	57·7	57·1	2·8	2·6	3·9	3·4
Average	61·5	61·5	62·4	62·5	4·32	4·02	4·84	4·48
Average percentage result	100	100	101	102	100	93	112	104

Comments by H. M. V. These experiments are specially valuable, in that two out of the three series were made by skilled typists. The average effects produced in subject K. by drinking claret are shown in the upper curves of Fig. 12. They correspond with the investigations previously described, and show that the consumption of claret

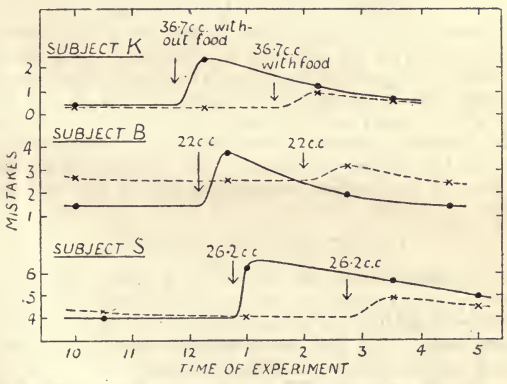

FIG. 12. Effects of Alcoholic Liquids on Subjects K., B., and S.

with food had less than half as much effect on the number of mistakes as its consumption without food. The effect on the typing time was quite marked, as this time was increased 12 per cent. when the claret

was taken without food, and 6 per cent. when it was taken with food. Though subject K. is a moderate drinker and not susceptible to alcohol, the effects of the claret without food on typing time and mistakes persisted to some extent for three and three-quarter hours. The quantity of port consumed contained less than two-thirds as much alcohol as the claret (i. e. 22 c.c. as against 36·7 c.c.), and, in correspondence with this fact, the port without food was found to influence the typing to about the same extent as the larger quantity of claret taken with food. Port taken with food had no appreciable effect upon the typing, or the conclusion arrived at in the target-pricking experiments is confirmed, viz. that for every individual there exists some moderate dose of alcoholic liquid which is without appreciable influence on neuro-muscular co-ordination. It does not follow, of course, that such a dose is without effect on the more complex nervous processes of the brain.

In subject B. the effects of consumption of sherry, with and without food, are shown in the middle curves of Fig. 12. It will be seen that the effectiveness of the wine taken without food was more than twice as great as of that taken with food. The quantity of alcohol contained in the sherry was the same as in the port consumed by subject K., and hence it follows that subject B. was considerably more susceptible than K., in whom the port was without effect. Subject B. also made a series of experiments in which she took 13 oz. of claret (=36·7 c.c. alcohol) with food. This caused her mistakes to increase from 3·02 up to 5·06, whilst the same amount of claret caused K.'s mistakes to increase from 0·28 up to 0·98. With such differences in the scale of errors made under normal conditions, it is impossible to say which of the two subjects was most affected, for though the absolute increase of mistakes was three times as great in B. as in K., the *percentage* increase was not a third as great.

The experiments made by subject S. show that whilst the consumption, on an empty stomach, of brandy containing 26·25 c.c. of alcohol increased the typing errors 55 per cent., it increased them only 12 per cent. (or 20 per cent. in comparison with the average errors made at 1 p.m.) when taken with food. The experimental results are shown graphically in the lowest curves of Fig. 12. The dose was rather a small one for a man, hence the effect on the mistakes was only moderate, though it persisted to a considerable extent for four hours in the foodless experiments. The typing time was increased 4 per cent. in the foodless experiments, and 1 per cent. in those with food.

Capt. M. Greenwood's Experiments.

"The experiments were carried out in a fashion similar to that described by Dr. Vernon, but the routine followed and the general conditions were modified in various particulars. Two sets of observations were made; the first was concerned with typewriting trials, the second with work upon an adding machine.

Typewriting Experiments. The machine used was a Blickensderfer Typewriter, the stroke of which is appreciably heavier than that of a standard machine. I have used such a machine for many years, but am neither a quick nor an accurate operator. The task selected was a passage consisting of nine Latin hexameter lines containing

TABLE XLV.—*Typing Experiments by M. G.*

Number of days on which experiments were made, and dates.	Experiments shortly before dinner.						Food taken at dinner—	Experiments shortly after dinner.					
	Slow typings.		Fast typings.		Mean.			Slow typings.		Fast typings.		Mean.	
	Time.	Mistakes.	Time.	Mistakes.	Time.	Mistakes.		Time.	Mistakes.	Time.	Mistakes.	Time.	Mistakes.
11 (May 6–17)	99·7	2·1	84·9	4·1	92·3	3·1	without alcohol.	100·6	1·7	86·0	3·6	93·3	2·6
6 (May 18–30)	95·2	1·1	82·9	3·5	89·1	2·3	with 1 glass port (18·5 c.c. alcohol).	96·4	1·3	84·2	4·3	90·3	2·8
4 (June 3–7)	95·2	1·3	81·4	4·1	88·3	2·7	without alcohol.	96·3	1·5	80·9	4·3	88·6	2·9
3 (June 8–14)	95·3	1·8	81·5	3·4	88·4	2·6	with 2 glasses port (37 c.c. alcohol).	93·7	2·1	82·5	6·5	88·1	4·3
5 (June 17–21)	92·1	1·1	80·2	3·6	86·2	2·4	without alcohol.	95·4	1·2	82·3	2·6	88·8	1·9

355 letters, spaces, or stops, while 18 further movements were needed for striking capitals and moving the paper carrier. Each day's experiments consisted of typing the passage eight times, four times before dinner and four times after dinner. Each set of four typings comprised (*a*) a first *slow* typing, the passage being written down at about the pace I usually adopt for letter writing, (*b*) a *fast* typing, i. e. one made at a rate which seemed subjectively a good deal faster than (*a*) but not so much faster that I had any difficulty in striking the keys, (*c*) was a repetition of (*a*), and (*d*) was a repetition of (*b*). Hence each series comprised two 'slow' and two 'fast' trials. The actual time at which the before-dinner series was carried out varied, but was usually between 8.30 and 8.45 p.m. (summer time) and always within a few minutes of dining. The after-dinner series was arranged to commence from 30 to 45 minutes after the alcohol had been drunk.

Alcohol was taken in the form of port wine of known strength; either one or two glasses were drunk, the actual quantities of absolute alcohol taken being 18·5 and 37 c.c. On the non-alcohol evenings I drank tea with my dinner, either two or three teacupfuls of an ordinary infusion without sugar. I adopted this practice because the disadvantage of using a caffein-containing beverage on the control evenings seemed outweighed by the advantage of preserving the normal routine, it being my regular practice to drink either a glass of wine or some cups of tea with my evening meal.

The result of the whole series of experiments, which extended from May 6 to June 21, are set out in Table XLV.

A scrutiny of this Table shows that, whether one considers speed or average mistakes, the first alcohol series, where 18·5 c.c. (one glass of port) were taken, is not differentiated from the general level; on the strength of these experiments it would be impossible to say that such a quantity of alcohol affected either speed or accuracy. The case is altered when we come to the larger quantity of 37 c.c., and I have compared the experiments when this quantity of alcohol was drunk with the means of the previous and succeeding non-alcohol series (after-dinner observations), paying attention to the probable errors. The results of the test are shown in Table XLVI. It will be seen

TABLE XLVI.—*Differences between the Means of Experiments with 37 c.c. of Alcohol and those of the Control Periods, (June 3–7 and 17–21).*

After Food Series.

	Time.	*Errors.*
1st. typing (slow)	-1.5 ± 2.3	$+0.49 \pm 0.53$
2nd. ,, (fast)	$+0.8 \pm 1.8$	$+2.91 \pm 0.97$
3rd. ,, (slow)	-2.8 ± 1.9	$+1.6 \pm 0.60$
4th. ,, (fast)	$+0.8 \pm 1.9$	$+3.22 \pm 0.86$

that in no case is the difference between speeds of significance having regard to the probable errors, but in both of the 'fast' typing trials the alcohol series shows an increase of mistakes nearly thrice the probable error of the difference. Hence it seems incontestable that

two glasses of port wine did cause a decided deterioration in the quality of the work done.

Since in these experiments, which are evidently the only practically important ones in my typing series, there was so little difference in the speeds of corresponding tests, the direct comparison of mistakes is sufficiently instructive; taking mean values of the four trials, the deterioration in the alcohol series as compared with the average of preceding and succeeding series is expressed by an increase of nearly 80 per cent. in the number of mistakes. This result agrees reasonably with Dr. Vernon's general average increase of 69 per cent. when 30 c.c. of alcohol were taken with food, but there are differences of detail between our findings, for while Dr. Vernon saw the maximum effect in the slower typings, I find the reverse. A not improbable explanation of this divergence in detail is that my 'slow' rates represent a routine of work performance which is very familiar to me; that is to say, I have for years used a typewriter and at about the same rate, hence typing at or about this rate is a habit ingrained and not easily disturbed. On the other hand, the 'fast' rates are not normal to me but specially acquired for these experiments, and liable consequently to be disturbed by drug action or otherwise with greater facility.

I think it is of importance to take account of the interruption of habit in experiments of this kind. I suppose most sedentary workers lead regular lives, particularly with respect to the routine of their meals. I have, for certainly ten years, been accustomed to drink a small quantity of wine at dinner, but I cannot recall ever taking more than a single glass of a fortified wine *when I intended to do any work after dinner*. It is a matter for consideration whether the fact that (in the 37 c.c. experiments) my routine was broken through may not have influenced the result. While a single glass of port wine produces in me no subjective effects save a slight increase of well-being, two glasses lead to an appreciable vertigo. The fact, however, that the deteriorating effect in any case is more accentuated at the rapid rates of typing, where there is less leisure for introspection than at the slow rates, is possibly significant.

Adding-machine Experiments. The Burroughs adding machine, the instrument employed, is provided with a series of keys arranged in nine parallel rows. In the model used in our experiments each row consists of nine keys; the highest row is of nine 9's, the second row of nine 8's, and so on. To operate the machine one depresses the appropriate keys with the fingers of the left hand, and the required numbers having been thus set upon the key-board, the addition is performed by pulling back with the right hand, and then letting fly, a lever at the side of the keyboard. The differences between the technique of this machine and that of typewriting are considerable. The keys are only depressed by the fingers of the left hand (in our practice only the index, middle and ring fingers are used), the other hand being reserved for operating the lever. The actual physical work, although slight, is greater than in typing, entirely on account of the manipulation of the lateral lever, the depression of the keys themselves being easier than on a typewriter keyboard and needing little impact. The keys being set very close together, it is easy to strike the key adjacent to the one intended.

The task chosen was to reproduce 123456789 thirty times, involving 270 movements to depress keys and 30 operations of the setting lever. At first it was found a little difficult to keep count, the number actually recorded often proving to be 29 or 31, but this error became rare after a little practice. The test appears to me to reproduce very well the conditions of light lathe work in factories or of several operations in cartridge-case making. A number of fine co-ordinated muscular movements are necessary; the physical energy needed is slight while the intellectual demands are negligible. The task is in fact very monotonous. At first, experiments were carried out at various hours of the day, but those reported upon in this paper are confined to two daily series: (1) the early series carried out after lunch, (2) the late series carried out a quarter of an hour to half an hour after tea (5 p.m.), at which meal two or two and a half cups of tea were drunk. In the alcohol-with-food experiments, claret was taken at lunch, the volume of claret drunk being 150 c.c., or rather less than a quarter of a bottle, and containing 15·3 c.c. of alcohol. In the without-food experiments, 190 c.c. of claret were drunk containing 19·4 c.c. of alcohol. This latter quantity contained approximately the same volume of alcohol as the one glass of port wine taken in the typing experiments, and was adopted after the apparently slight efficacy of the smaller dose with food had shown itself in the results. In the fasting experiments the alcohol was drunk at the normal hour for food and the tests were made half an hour later. Table XLVII is a record of the experiments made on M. G.

TABLE XLVII.—*Adding-machine Experiments by M. G.*

Number of days on which experiments were made, and dates.	Time and conditions of experiments.	Mean of two slow experiments.		Mean of two fast experiments.		Mean of slow and fast experiments.	
		Time.	Errors.	Time.	Errors.	Time.	Errors.
10 (May 1–21)	After lunch without alcohol	75·7	1·5	66·7	3·4	71·2	2·4
	After tea without alcohol	76·0	1·4	67·7	5·5	71·8	3·4
6 (May 22–29)	After lunch, with 150 c.c. claret (= 15·3 c.c. alcohol)	73·9	1·7	64·1	5·1	69·0	3·4
	After tea without alcohol	72·3	2·3	62·4	3·7	67·4	3·0
5 (May 30–June 6)	After lunch without alcohol	75·6	1·4	64·2	3·8	69·9	2·6
	,, tea ,, ,,	74·5	1·0	61·9	3·8	68·2	2·4
6 (June 7–14)	Early in afternoon, ½ hr. after taking 190 c.c. claret (= 19·4 c.c. alcohol) without food	71·1	2·0	62·4	7·2	66·8	4·6
	After tea without alcohol	73·0	0·4	62·3	2·6	67·7	1·5
5 (June 17–21)	After lunch without alcohol	70·0	1·5	63·5	3·7	66·8	2·6
	,, tea ,, ,,	68·0	0·5	62·0	3·0	65·0	1·8

It will be seen that series of experiments without alcohol were made before and after the alcohol experiments. If the alcohol experiments with food be compared against a mean of the non-alcohol experiments made before and after, the deterioration—measured in terms of mistakes—amounts to 42 per cent., whilst a similar comparison in the fasting experiments shows a deterioration of 74 per cent. This latter figure is of the same order of magnitude as the deterioration experienced in the typing series when twice the volume of alcohol was taken but with a meal. The result is therefore in agreement qualitatively with those of Dr. Vernon and other investigators, testifying to the specially unfavourable action of alcohol taken on an empty stomach. Quantitative comparison is naturally excluded by the variations of other conditions (time of day, nature of task, etc.)

Table XLVIII shows the differences between the means of the time and errors observed in the alcohol experiments and in the control periods. The probable errors have been computed by the aid of the appropriate standard deviations determined from the whole of the experiments, excepting those of the early afternoons following the drinking of alcohol.

TABLE XLVIII.—*Differences between the Means of Experiments with 15·3 c.c. and 19·4 c.c. of Alcohol and those of the Control Periods.*

	Speed of experiment.	*Time.*	*Errors.*
15·3 c.c. alcohol with food	1. slow	-1.8 ± 1.67	0 ± 0.49
	2. fast	$+1.5 \pm 1.25$	$+2.0 \pm 0.74$
	3. slow	$+0.1 \pm 1.76$	$+0.5 \pm 0.34$
	4. fast	-1.3 ± 1.14	$+1.5 \pm 0.84$
19·4 c.c. alcohol without food	1. slow	-1.2 ± 1.56	$+0.5 \pm 0.46$
	2. fast	-1.6 ± 1.16	$+5.0 \pm 0.72$
	3. slow	$+0.6 \pm 1.63$	$+0.5 \pm 0.33$
	4. fast	-1.2 ± 1.15	$+1.8 \pm 0.82$

I think that the close concordance between the adding-machine series and the typing experiments strengthens the conclusions mutually. Two further sets of experiments were carried out by my colleagues C. M. T. and H. M. W. The observations were confined to a comparison of the effects of alcohol (150 c.c. of the claret) taken with food.[1] C. M. T.'s experiments comprised one week with alcohol and the weeks before and after without alcohol. The experiments agreed in results with those of M. G., for the second and fourth, or the rapidly executed tests, showed an increase of mistakes, the difference of the fourth tests being more than thrice the probable difference. The two slow trials were not materially affected by alcohol.

H. M. W., being obliged to leave London on official business before the experiments were completed, her observations only covered a week

[1] Neither lady was in the habit of drinking wine at lunch.

without alcohol and the following week when alcohol was taken at lunch; consequently the effect of practice should favour the experiments done with alcohol. The series showed a deterioration (measured by the average number of mistakes) in the two quickly executed tests, but in one of these the difference was but little larger than its probable error. The two slow trials were unaffected. The four sets of observations, viz. typing and adding tests by M. G., and adding tests by H. M. W. and C. M. T., agree very well with one another and support the following conclusions:

1. Small doses of alcohol, well within the limits of what would be deemed by all moderation, do not sensibly affect the speed of performance of such semi-automatic operations as typing a memorized passage or setting down and adding a row of figures on a mechanical calculator, but gravely depreciate the accuracy of performance.

Two glasses of port wine in a person accustomed to drink a glass of wine have this effect when the wine is taken with food. Less than this is sufficient to produce a result if taken on an empty stomach.

2. Should the task set be very familiar to the subject, the above conclusion does not hold. Such small doses of alcohol did not exert any measurable effect upon the number of mistakes in either a typing or adding test made with a speed of performance to which the subject had become familiarized by long practice.

None of our experiments bring out any effect upon the slow addings or typings, experiments which were made at a speed to which we were quite accustomed.

3. A corollary of 2 is that we cannot confirm Dr. Vernon's observation attesting the particularly unfavourable effect of alcohol upon the first of a series of experiments performed under its influence. For the reason just given, this does not involve any contradiction between the two sets of experiments. We had not realized beforehand the possible importance of this habit factor, and in order to test the point as to an inferiority of first trials it would have been necessary to reverse the order and to have made the series run fast, slow, fast, slow, instead of the other way round.

From the practical standpoint, these results seem to me to emphasize the importance of Dr. Vernon's general conclusion that moderate doses of alcohol affect the accuracy of semi-automatic work more than a casual observer might suppose, while the way in which this effect seems accentuated in work performed under relatively novel conditions is much what ordinary experience would lead us to expect.

Lastly, as to the experimental method, I think that the irregularity of the time equivalents of mistakes and the seeming impossibility, at any rate with short series of experiments, of arriving at a quantitative measure of the effects of practice, suggest that in future experiments it would be advisable to perform the tests at as uniform a rate as possible, measurements not being made until a training period has elapsed sufficient in length to render subsequent improvement with practice very slight."

IV. General Conclusions.

The experimental evidence which has been adduced concerning the action of alcohol on manual work and neuro-muscular co-ordination is considerable in bulk, but, by reason of its multiple origin, is rather disconnected. As it has been impossible to present it in such a manner as to indicate the broad conclusions which may be deduced, it is worth while to attempt to summarize such conclusions now.

We have seen that experiments were made upon eight men and five women altogether, and that all of them, with one doubtful exception, showed some reaction to the very moderate doses of alcohol and alcoholic liquids employed. This reaction was invariably in the direction of diminished control of the muscles, as was proved by the increase in the number of typing and adding-machine mistakes, by diminished typing speed, and by increased error in pricking a target. There was never any initial improvement, even of brief duration, such as Kraepelin sometimes observed in reaction-time experiments, and in simple mental work such as reading aloud. At the same time it was found that in some of the subjects a small dose of alcohol, if taken with food, might induce no measurable reaction whatever. This non-reactive dose amounted to one glass of port (= 18·5 c.c. alcohol) in M. G. and to 4 oz. port (= 22 c.c. alcohol) in K., but it must have been considerably less than this in the more susceptible subjects, such as K. D. V. and B. When taken on an empty stomach, alcohol was found to be about twice as toxic as when taken with food, and consequently even 15·3 c.c. of alcohol (in the form of claret) caused some reaction in M. G., whilst 11·2 c.c. of pure alcohol, suitably diluted, caused a considerable reaction in K. D. V. A dose of 20 c.c. of alcohol caused a very small increase in the typing mistakes of H. M. V. and N. B. D., but 22 to 26·2 c.c. of alcohol (taken as port, sherry, or brandy) caused a considerable reaction in K., B., and S. However, individuals vary enormously in susceptibility, for it was found that a student who had, a year previously, been rather a heavy drinker, showed little or no reaction to a dose of whisky containing 45 or 60 c.c. of alcohol.

The types of manual work investigated are not very typical ones, as they involve quicker movements than those made in the majority of industries, but on the other hand the target-pricking experiments necessitated slower and more deliberate movements than those usually met with. Hence it may be concluded that the effects produced by alcohol in these very different types of muscular movement would apply equally to the movements of intermediate speed which are required in many classes of manual work. In all work with the hands requiring skill and delicacy of muscular control, one may be confident that, whilst strictly moderate quantities of alcoholic liquors, taken by persons accustomed to alcohol, may not appreciably reduce manual skill, they can seldom if ever improve it. Moreover, such persons continually run the risk of finding their manual skill quite appreciably reduced if they happen to take their alcohol on an empty stomach instead of a full one. It would be far better for them to avoid the risk altogether by postponing their consumption of alcohol till the day's work is over.

The target-pricking experiments agree with the typing experiments in indicating that very moderate doses of alcohol are without appreciable effect. The experiments with larger doses, if confirmed on other subjects, yield a result of some practical importance. They showed that, above a certain limit, the increasing lack of neuromuscular co-ordination varies directly with the amount of alcohol consumed. There is no sudden increase of effect produced by a comparatively small additional dose. In other words, the man who, when convicted of drunkenness, pleads the unexpected effects of a single extra glass has no scientific support for his contention. He must have been nearly drunk before the final glass was taken. The toper who occasionally finds that the quantity of alcohol which he can usually carry with comfort has led to unexpected intoxication has probably made some change in the conditions under which he consumed his drink. He may have consumed it a longer time than usual after his last meal, and thereby have taken it on an empty stomach instead of a full one, or he may have consumed it more quickly, and so, for a few fatal minutes, have obtained a greater concentration of alcohol than usual in his blood.

In the preface to the book on Alcohol issued by the Advisory Committee, Lord D'Abernon propounds a number of questions upon which further knowledge is desirable, and some of these questions can be answered in part from the experimental evidence adduced. Firstly, he asks to what extent pure alcohol differs in its action from alcoholic beverages of corresponding strength. The reply is that it differs comparatively little. Different subjects do not all react alike, but on an average it appeared that wine and spirits are rather more toxic than pure ethyl alcohol of equal quantity and strength. As would be expected, the difference was not at all marked, for the quantity of higher alcohols and other narcotics present in matured wine and spirits is very small compared with that of ethyl alcohol. No experiments were made with immature spirits.

Another question concerned the effects of dilution. Experiments in which the dilution of alcohol varied from 5 per cent. to 40 per cent., or roughly in proportion as they vary in beer and in neat spirits, showed that the difference was not great. A 5 per cent. solution had about three-fourths as much effect on typing errors as 20 and 40 per cent. solutions, whilst dilute brandy, containing 10 per cent. of alcohol, had likewise about three-fourths as much effect on target-pricking errors as neat brandy containing 37 per cent. of alcohol. The difference of effect probably depends almost entirely on the rate of absorption. Thus 30 c.c. of alcohol, in 40 per cent. solution, has a volume of only 75 c.c., but in 5 per cent. solution it has a volume of 600 c.c., and it would be highly improbable that the alimentary canal could absorb this large volume of liquid as quickly as the small one. If it cannot, then the concentration of alcohol in the blood cannot reach so high a level, and the maximum toxic effect must likewise be less.

Another question concerns the effect of drinking alcohol with and without food. Upon this point a very large amount of evidence has been adduced, as it is one which has been curiously ignored by most previous investigators. As a rule, no mention whatever is made by

them as to the time which elapsed between the consumption of food and the consumption of the experimental dose of alcohol, though we have seen that this is a matter of extreme importance. All experiments ought to be made, so far as possible, on a full stomach or an empty one, and not under some intermediate and ill-defined conditions, such as would ensue if the alcohol were taken about two hours after food. The assumption made in the present experiments, that the stomach is practically empty three hours after food is taken, is not always correct, and it would have been better to have waited for four hours, but as a rule it would have been inconvenient to wait so long, seeing that the experiments lasted one and a half to two hours after the alcohol d been consumed.

The influence of food on the toxic action of alcohol depends on several factors. The food dilutes the alcohol considerably, but, more important than this, it greatly delays its absorption. The alcohol gets well mixed with the stomach contents, and thereby is prevented from coming into such frequent and intimate contact with the gastric mucous membrane as when it is taken without food. Again, the mixture of food and alcohol remains much longer in the stomach than does alcohol without food, and it is probable that the gastric mucous membrane absorbs alcohol considerably more slowly than the intestinal mucous membrane. If the food contains much fat, the fat not only delays the passage of the food from stomach to intestine, but it dissolves part of the alcohol, and this alcohol can only be absorbed when the fat is itself digested and absorbed. Thus I found that when a dose of 60 c.c. of alcohol was taken with a fatty meal, it produced less effect on typing than if it were taken with a fatless meal. On the other hand, the effect continued to a marked extent for three and three-quarter hours or more, though it had disappeared in the fatless experiments.

V. Summary.

The influence of alcohol on manual work and on neuro-muscular co-ordination was investigated in eight men and five women. In seven of the subjects observations were made on the accuracy and speed of typewriting: in three, on the accuracy and speed of working an adding machine, and in six, on the accuracy with which a target could be pricked.

In the typewriting experiments a memorized passage was typed frequently before and after the alcohol, and it was found that as a rule the speed was but little diminished, but the number of mistakes made was increased two- or even four-fold. It was found to be possible to correct for the variable speed, and obtain a measure of the alcohol effect in terms of mistakes only. The possible influence of mental impressions on the result was excluded by typing every day for alternate weeks with and without alcohol. As some of the series of experiments lasted for six weeks, and were consistent throughout, the effects observed can be accepted with confidence.

Alcohol produced some effect in all of the individuals tested by the typing and adding-machine methods. The degree of effect depended largely on whether the alcohol was taken on an empty

stomach or with food, for on an average it was about twice as toxic under the former conditions as under the latter. In the foodless experiments, one subject made 88 per cent. more typing mistakes after she drank 11·2 c.c. of alcohol. Another subject increased his adding-machine mistakes 74 per cent. after taking claret containing 19·4 c.c. of alcohol; another increased her typing mistakes 156 per cent. after drinking sherry containing 22 c.c. of alcohol.

In some subjects a moderate dose of alcoholic liquid, taken with food, produced no measurable reaction. Such a non-reactive dose amounted to one glass of port (= 18·5 c.c. alcohol) in a male subject, and to 4 oz. of port (= 22 c.c. alcohol) in a female subject.

The effect reached its maximum half an hour after taking alcohol on an empty stomach, and might completely disappear in two hours. When the alcohol was taken with food, the effect was slightly longer in reaching its maximum.

When alcohol (30 c.c.) was taken in 5 per cent. strength, the effect produced was about three-fourths as great as when it was taken in 20 per cent. or 40 per cent. solution. A similar difference was observed when taking diluted brandy (10 per cent. alcohol) and neat brandy (37 per cent. alcohol).

In the target method, rows of dots, made on squared paper fixed vertically at arm's length, were pricked at 3-minute intervals before and after the alcohol. The average distance of a prick from the centre was about 1·8 mm., but after taking 30 c.c. of alcohol the target-pricking error increased 12 per cent.; after taking 37·5 c.c. it increased 43 per cent., and it continued to increase in arithmetical progression with the dose of alcohol till it was 132 per cent. above the normal when 60 c.c. were taken. The influence of alcohol on target-pricking errors developed and disappeared synchronously with its influence on typing errors.

Experiments made on five subjects with claret and pure alcohol of equal alcoholic strength showed that claret was slightly the more toxic. Diluted brandy had slightly less effect than claret, but neat brandy slightly more.

One subject who, a year before, had been rather a heavy drinker, showed little if any reaction, even after drinking whisky containing 45 or 60 c.c. of alcohol. He was tested by the target method, and took the whisky three hours after food.

Table I.—*Normal Week.*

Date.	Mean times of typing.												Mean of slow and fast typings.	
	9.11 a.m.				6.51 p.m.				10.2 p.m.					
	Slow typing.		Fast typing.		Slow typing.		Fast typing.		Slow typing.		Fast typing.			
	Time.	Mistakes.	Time.	Mistakes.	Time.	Mistakes.	Time.	Mistakes.	Time.	Mistakes.	Time.	Mistakes.	Time.	Mistakes.
Feb. 8	127·7	1·7	120·3	3·0	129·0	1·5	122·0	4·5	128·7	1·5	124·2	3·9	125·3	2·7
,, 9	122·7	1·7	117·3	2·3	128·3	0·3	121·3	2·3	124·7	1·3	119·2	3·3	122·4	1·9
,, 10.	127·1	1·3	119·0	3·0	122·3	1·7	117·7	3·0	127·0	1·0	120·0	3·5	122·2	2·3
,, 11	128·7	2·0	120·0	3·7	[124·7	1·0	118·1	3·0]	127·0	0·5	118·0	3·7	122·7	2·3
,, 12	127·7	1·3	119·7	2·3	124·7	0·7	115·3	0·3	125·3	3·0	116·3	3·0	121·5	2·1
,, 13	128·7	2·0	113·0	2·2	119·0	1·0	114·0	3·0	123·0	1·3	112·0	5·3	118·3	2·5
Mean	127·1	1·7	118·2	2·8	124·7	1·0	118·1	3·0	126·0	1·4	118·4	3·8	122·1	2·3

No typings were made at 6.51 p.m. on February 11, the data inserted being the mean of the results obtained on other days. On February 8 typings were made at 8.14 instead of 6.51 p.m.

TABLE II.—*30 c.c. Alcohol with Food at 7.15 p.m.*

Date.	Mean times of typing.																Mean of slow and fast typings.	
	9.15 a.m.				6.41 p.m.				9 p.m.				10.40 p.m.					
	Slow typing.		Fast typing.		Slow typing.		Fast typing.		Slow typing.		Fast typing.		Slow typing.		Fast typing.			
	Time.	Mistakes.	Time.	Mistakes.	Time.	Mistakes.	Time.	Mistakes.	Time.	Mistakes.	Time.	Mistakes.	Time.	Mistakes.	Time.	Mistakes.	Time.	Mistakes.
Feb. 14	119·3	0·3	111·7	5·7	119·0	1·0	110·0	3·2	123·6	2·1	111·8	4·5	123·7	0·7	113·7	2·8	116·6	2·6
„ 15	120·7	1·3	109·0	2·5	113·0	1·0	107·3	2·3	121·0	1·7	106·7	3·8	124·3	1·7	114·0	2·0	114·5	2·0
„ 16	117·7	0·3	112·7	3·7	124·3	0·3	110·0	3·7	117·3	1·8	112·0	5·7	123·0	0·7	116·3	3·0	116·7	2·4
„ 17	120·3	1·0	117·7	2·2	118·7	0·5	108·7	3·0	126·3	2·7	109·7	2·8	120·0	1·3	110·7	3·7	116·5	2·2
„ 18	117·7	0·8	112·3	3·7	120·3	1·3	107·7	3·8	119·7	1·0	111·3	3·3	117·7	1·5	111·3	3·5	114·8	2·4
„ 19	121·3	0·2	107·3	3·3	122·7	1·0	107·3	1·8	119·0	2·3	109·0	4·3	125·7	3·0	110·7	3·2	115·4	2·4
„ 20	118·3	1·0	113·3	2·8	115·3	0·0	106·0	2·0	114·0	1·3	113·0	4·8	120·0	1·5	107·0	2·5	113·4	2·0
Mean	119·3	0·7	112·0	3·4	119·0	0·7	108·1	2·8	120·1	1·8	110·5	4·2	122·1	1·5	112·0	3·0	115·4	2·3

TABLE III.—*30 c.c. Alcohol without Food at 5 p.m.*

Date.	Mean times of typing.																Mean of slow and fast typings.	
	4.50 p.m.				5.52 p.m.				7.6 p.m.				9.14 p.m.					
	Slow typing.		Fast typing.		Slow typing.		Fast typing.		Slow typing.		Fast typing.		Slow typing.		Fast typing.			
	Time.	Mistakes.	Time.	Mistakes.	Time.	Mistakes.	Time.	Mistakes.	Time.	Mistakes.	Time.	Mistakes.	Time.	Mistakes.	Time.	Mistakes.	Time.	Mistakes.
Feb. 21	111·7	1·0	106·7	3·3	116·3	4·7	110·7	5·7	116·7	0·8	105·7	3·5	115·3	1·2	10 5·3	3·3	111·1	2·9
,, 22	113·3	1·8	101·3	2·5	120·0	4·5	111·0	5·5	118·0	1·7	106·0	3·7	115·0	1·0	108·3	3·2	111·6	3·0
,, 23	106·0	0·7	101·3	3·7	114·3	3·7	108·0	7·1	114·3	1·0	105·7	1·8	120·3	1·1	109·7	4·8	110·0	3·0
,, 24	115·7	1·5	104·0	2·3	116·0	2·3	109·7	6·0	108·0	1·3	101·7	4·3	119·0	1·8	107·7	3·7	110·2	2·9
,, 25	108·3	1·1	99·7	3·5	113·0	1·8	103·0	3·1	111·0	2·1	105·3	4·1	113·3	0·8	97·3	1·5	106·4	2·3
,, 26	110·3	1·0	101·7	2·8	115·0	2·5	107·7	6·8	115·7	1·1	104·7	3·8	114·0	1·5	109·0	3·0	109·8	2·8
,, 27	106·3	0·8	101·0	3·0	114·0	2·5	106·3	4·1	114·0	2·0	104·0	3·5	114·0	2·0	105·0	3·3	108·1	2·7
Mean	110·2	1·1	102·2	3·0	115·5	3·1	108·1	5·5	114·0	1·4	104·7	3·5	115·8	1·3	106·0	3·3	109·6	2·8

The last typing on February 24 was made at 10.48 p.m., and on February 25 at 8.11 p.m.

TABLE IV.—*60 c.c. Alcohol with Food at 7.15 p.m.*

Date.	Mean times of typing.																Mean of slow and fast typings.	
	9.10 a.m.				6.38 p.m.				8.51 p.m.				10.42 p.m.					
	Slow typing.		Fast typing.		Slow typing.		Fast typing.		Slow typing.		Fast typing.		Slow typing.		Fast typing.			
	Time.	Mistakes.	Time.	Mistakes.	Time.	Mistakes.	Time.	Mistakes.	Time.	Mistakes.	Time.	Mistakes.	Time.	Mistakes.	Time.	Mistakes.	Time.	Mistakes.
Feb. 28 *	(107·7)	(0·5)	(103·0)	(1·8)	(111·0)	(1·7)	(103·3)	(2·0)	(111·0)	(2·8)	(105·0)	(3·0)	(101·3)	(2·3)	(109·3)	(2·0)	(107·6	(2·0)
Mar. 1	110·3	1·5	105·7	3·7	107·7	2·1	101·7	5·5	112·7	5·0	105·0	4·8	111·0	2·0	105·3	5·0	107·4	3·7
,, 2	111·7	2·7	105·7	4·1	112·7	2·7	103·0	2·8	110·7	1·8	107·3	5·5	108·7	2·7	104·3	3·5	108·0	3·2
,, 3	113·1	1·7	102·2	2·8	110·0	1·5	104·5	3·2	112·1	4·3	106·1	8·3	108·5	2·1	101·9	4·7	107·3	3·6
,, 4	113·6	3·7	107·1	4·0	108·7	1·7	99·9	4·7	109·2	4·5	106·6	5·3	112·6	2·8	101·9	3·7	107·3	3·8
,, 5	108·3	2·1	99·8	4·0	108·7	1·5	99·3	3·7	111·9	5·3	100·0	3·3	107·3	3·0	98·7	5·7	104·3	3·6
,, 6	113·3	1·5	101·8	4·3	109·1	1·3	102·3	2·8	111·7	4·8	108·5	6·3	112·5	3·0	102·1	3·0	107·7	3·4
Mean	111·7	2·2	103·7	3·8	109·5	1·8	101·8	3·8	111·4	4·3	105·4	5·6	110·1	2·6	102·4	4·3	107·0	3·5

* On February 28, 45 c.c. of alcohol were taken instead of 60 c.c., so the data of this day are not averaged with the rest.

Table V.—*Normal Week.*

Date.	Mean times of typing.																Mean of slow and fast typings.	
	9.10 a.m.				6.42 p.m.				8.58 p.m.				10.42 p.m.					
	Slow typing.		Fast typing.		Slow typing.		Fast typing.		Slow typing.		Fast typing.		Slow typing.		Fast typing.			
	Time.	Mistakes.	Time.	Mistakes.	Time.	Mistakes.	Time.	Mistakes.	Time.	Mistakes.	Time.	Mistakes.	Time.	Mistakes.	Time.	Mistakes.	Time.	Mistakes.
Mar. 7	110·7	2·0	103·5	3·3	110·7	1·5	99·2	2·8	113·5	1·1	105·3	3·8	109·9	0·7	106·0	2·7	107·3	2·2
,, 8	113·3	3·1	106·9	5·3	106·4	0·7	98·8	3·5	112·6	1·0	101·2	1·7	108·5	1·7	106·3	4·5	106·8	2·7
,, 9	109·7	1·5	105·4	2·8	109·6	2·0	100·9	2·0	108·2	1·3	104·5	3·8	110·4	0·0	108·0	3·1	107·1	2·1
,, 10	112·9	1·0	101·1	2·5	108·8	1·0	106·7	2·7	111·5	1·0	100·5	2·3	111·4	1·0	105·7	1·8	107·3	1·7
,, 11	113·9	2·1	106·9	4·1	109·0	1·3	101·0	1·1	107·7	0·7	102·2	3·3	111·9	1·8	103·7	0·8	107·0	1·9
,, 12	112·7	1·5	99 7	1·8	106·1	0·5	98·2	2·1	111·1	0·7	100·5	2·8	112·2	1·0	103·3	3·5	105·5	1·7
,, 13	112·4	2·3	99·3	3·0	111·7	0·8	101·7	2·5	108·5	0·7	99·8	2·7	112·6	1·8	107·0	2·7	106·6	2·1
Mean	112·2	1·9	103·3	3·3	108·9	1·1	100·9	2·4	110·4	0·9	102·0	2·9	111·0	1·1	105·7	2·7	106·8	2·1

OCLC